2010 winter

Membrane News Twente

News magazine of the Membrane Technology Group

MNT, p/a University of Twente - TNW/MTO
PO Box 217 , NL-7500 AE Enschede, Netherlands
membrane@utwente.nl - www.utwente.nl/tnw/mtg
Telephone: +31 (0) 53 489 2950 - Fax: +31 (0) 53 489 4611

European Membrane Institute Twente

The Membrane Technology Group of the University of Twente is responsible for teaching and training of undergraduates, master and PhD-students. Since the start of the group, almost 40 years ago, a lot of knowledge is build up about membrane formation, application and characterization. During all those years, much equipment was purchased or custom made developed.

Over the years, many research questions came from the industry to help them to develop specific membranes or to carry out a characterization study. These short or middle long-term research assignments do not fit into the program of the Dutch PhDs that have a defined project description and duration of exactly 4-years. Next to this, PhD-students have to present and to publish their results. This often conflicts with the interest of companies. To offer the industry and public organizations a platform for short and middle long-term research and development projects on a confidential basis Prof. Heiner Strathmann started in 1995 together with Dr. Geert-Henk Koops the European Membrane Institute Twente.

Mission statement

"EMI Twente acts as the interface between the academic research performed in the Membrane Technology Group and the industry"

We create, transfer and translate our (fundamental) scientific knowledge into applications, products and processes

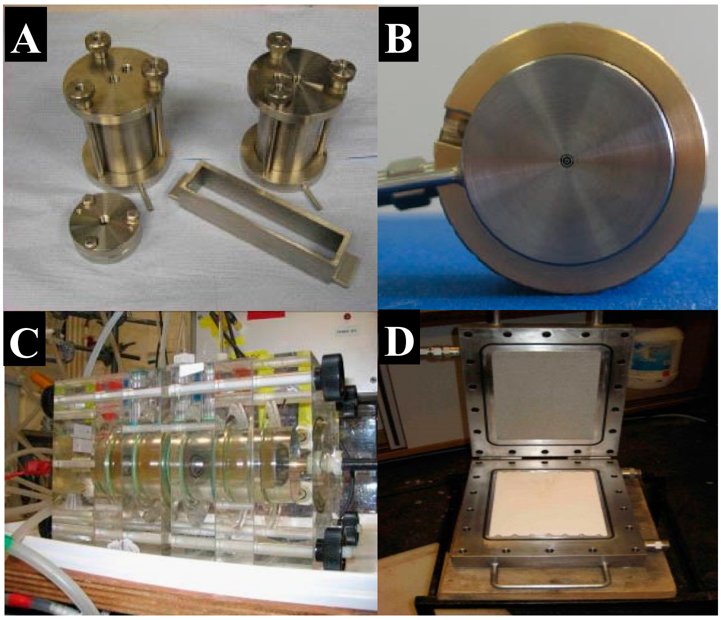
Although the EMI is part of the Membrane Technology Group, for reasons of confidentiality and quality no students are involved the EMI projects. Only highly skilled staff that has a long record of accomplishment in membrane production and characterization carries out the EMI projects.

The EMI Twente has broad experience in membrane development, especially in hollow fiber membranes for a variety of membrane applications; from gas separation to microfiltration and from electrodialysis to (P)RO membranes and membrane contactors.

Since the start of the EMI in 1995 it has performed various projects on a bilateral basis for over 120 different companies from Europe (The Netherlands, United Kingdom, Norway, Denmark, Germany, Belgium, France, Italy, Austria, Switzerland), Turkey, India, USA, Canada and Japan and several middle east countries. The duration and type of projects varied from a few days (autopsies, membrane characterization, etc.) to approximately 4 years (membrane development). Typical feasibility and application studies take 1 – 4 months. For these types of projects, written agreements with regard to research content as well as secrecy are standard procedures.

To offer these services the EMI has access to the knowledge and infrastructure of the Membrane Technology Group.

Next to research and characterization services EMI also offers membrane related equipment like: A4, A5, A6 test cells for gas



Examples of characterization equipment and test cells available at the EMI. A) stirred cells, gas permeation cell and casting knife. B) triple layer spinneret C) membrane resistance cell. D) high pressure flat cell.

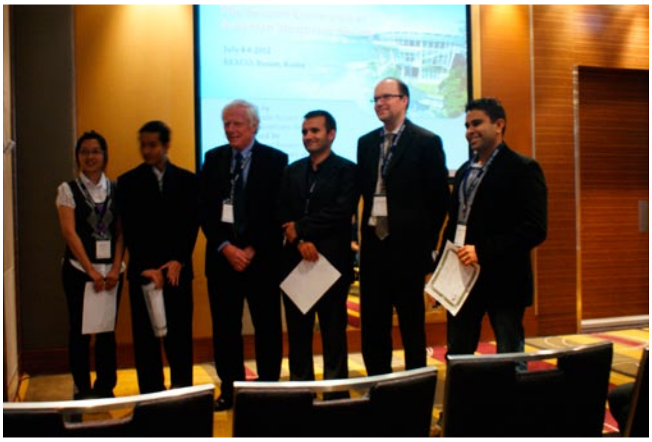
separation and nanofiltration, stirred cells for liquid filtration, spinnerets for hollow fiber spinning and even complete pilot scale hollow fiber spin lines. Further the EMI offers literature and market studies and consultancy.

Examples of characterization equipment and test cells available at the EMI. A) stirred cells, gas permeation cell and casting knife. B) triple layer spinneret C) membrane resistance cell. D) high pressure flat cell.

The EMI is headed by Zandrie Borneman and Antoine Kemperman.

More information about the EMI can be found on the website: www.utwente.nl/tnw/emi/ or via a link on the website of the Membrane Technology Group (www.membrane.nl).

AMS6/IMSTEC10 oral presentation award for Mayur Dalwani



At the Aseanian Membrane Society 6 / International Membrane Science and technology conference 2010 in Sydney-Australia, Mayur Dalwani won the oral presentation prize. The 5 presentation awards that were sponsored by Professor Chris Fell and the Membrane Society of Australia consist of a certificate and 200 Australian dollars. Mayur Dalwani's presentation was titled "Nanofiltration for extreme conditions". He discussed how he fabricates composite membranes via the interfacial polymerization technique and the effect of feed pH on the membrane performance.

For more information, please contact Dr. Nieck Benes (n.e.benes@utwente.nl; phone: +31 53 489 4288)

M. Dalwani, N.E. Benes, G. Bargeman, D. Stamatialis, M. Wessling, A method for characterizing membranes during nanofiltration at extreme pH, Journal of Membrane Science, vol 363 (2010), page 188-194.

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.

Editors
Matthias Wessling
Kitty Nijmeijer
Enver Güler
membrane@utwente.nl
www.membrane.nl

Hollow fiber membrane with inner structures. Picture by Zeynep Culfaz.

University of Twente hosts ICOM2011

ICOM 2011

Call for Papers

ICOM
International Congress on
Membranes and Membrane Processes

Amsterdam, The Netherlands
July 23 till July 29, 2011
www.icom2011.org

Welcome

The organizing committee of ICOM 2011 has the pleasure to invite you to ICOM 2011. The ICOM, the International Congress on Membranes and Membrane Processes, is the world's largest conference on fundamental and applied membrane science, engineering and technology. It offers a platform for extensive exchange of ideas, thoughts and discussions on membranes and membrane processes.

Organizing committee

ICOM 2011 is organized by the Membrane Technology Group of the University of Twente, Enschede, The Netherlands (www.membrane.nl). The conference is chaired by Dr. Kitty Nijmeijer, Dr. Antoine Kemperman and Prof. Matthias Wessling.

Conference topics

ICOM 2011 covers the multidisciplinary chain of membrane science and technology ranging from molecule to process. Contributions can be fundamental or applied in nature. Abstracts for both oral and poster presentations are accepted. All abstracts will be evaluated by the scientific committee of ICOM 2011.

Call for papers

We strongly encourage people working in the field of membrane science and technology to submit a conference abstract. Authors are requested to submit their abstract electronically. Deadline for abstract submission is January 15, 2011. More information on the submission procedure and the abstract template will be available at the conference website (www.icom2011.org).

Venue

ICOM 2011 will take place in the RAI in Amsterdam (www.rai.nl). The RAI is one of the largest conference centers of Europe. It is located in very close distance to the city centre of Amsterdam, which is easily accessible by public transport.

Important dates

October 15, 2010 Website open for abstract submission
December 1, 2010 Website open for early registration
January 15, 2011 Deadline for abstract submission
March 1, 2011 Notification of authors
April 1, 2011 Deadline for early registration
May 1, 2011 Conference program available
July 1, 2011 Abstracts available on website
July 23-24, 2011 Pre-conference workshops
July 24-29, 2011 ICOM 2011

More information

More information can be obtained at our website:
www.icom2011.org

or by sending an e-mail to:
info@icom2011.org.

EMS
European Membrane Society

Microstructured hollow fibers and microsieves: Fabrication, characterization and filtration applications

Microstructuring membranes serve various purposes, such as increased surface area and altered flow profiles, concentration polarization and fouling behavior. Phase separation microfabrication (PSμF) is a technique that can be used to make microstructured membranes in both sheet and hollow fiber geometries. Microstructured templates are used to create microstructures on the surface of the membranes, which are formed via phase separation of a polymer solution in a nonsolvent.

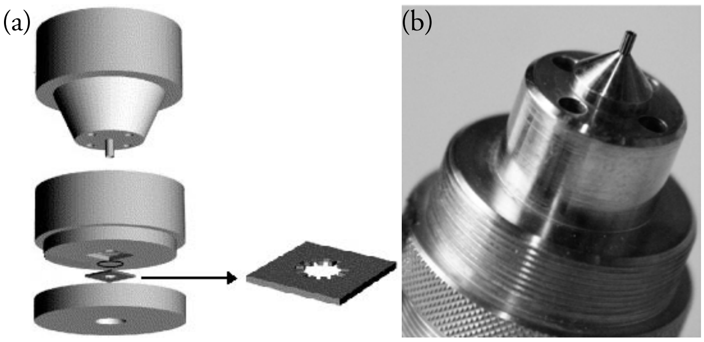


Figure 1 - (a) Schematic of the spinneret used to fabricate hollow fibers with microstructured outer surface. (b) Picture of the needle of the spinneret used to fabricate hollow fibers with microstructured inner surface.

Special spinnerets are used to prepare hollow fibers with microstructured surfaces (Figure 1). During the fabrication of hollow fibers with microstructured outer surfaces, the main parameters affecting the structure of the surface are the air gap used and the viscosity of the polymer dope, which strongly affects the rate of reflow of the microstructured shape towards a round one (Figure 2). The intrinsic permeability and the pore size distribution of these structured hollow fibers and the round fibers prepared under the same conditions are similar. This implies that the same separation can be achieved by both kinds of fibers, while the structured fibers produce more permeate per module volume due to the enhanced surface area per volume.

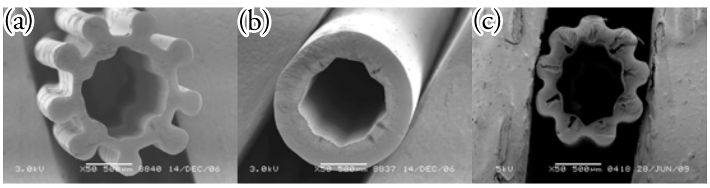


Figure 2 - Hollow fibers spun using (a) a high viscosity polymer dope and a short air gap, (b) a high viscosity polymer dope and a long air gap, (c) a low viscosity polymer dope and a short air gap.

The fabrication of hollow fibers with microstructured inner surfaces is also affected by other parameters such as the flow rates of the polymer dope and the bore liquid. Using a high bore liquid flow rate can destroy the microstructure on the inner surface (Figure 3.a). A high polymer dope flow rate, which results in thick fiber walls can cause the bore to take an oval shape (Figure 3.b). Under appropriate fabrication conditions, hollow fibers with undeformed, microstructured bores can be obtained (Figure 3.c).

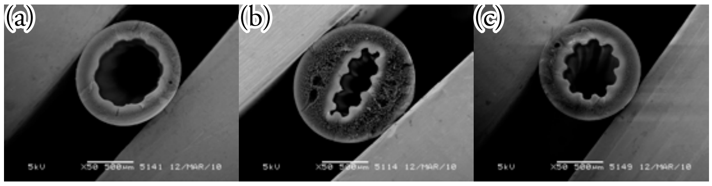


Figure 3 - Hollow fibers spun using a spinneret with a microstructured needle and (a) a high bore liquid flow rate, (b) a high polymer dope flow rate, (c) optimum bore liquid and polymer dope flowrates.

The skin layer thickness of asymmetric membranes can be investigated using a colloidal filtration method with gold nanoparticles. When the gold particles, which are larger than the pores in the skin layer of the membrane, are filtered from the support side towards the skin, they accumulate before the skin layer which they cannot penetrate through. The backscattered electron signal in the scanning electron microscope can distinguish between different atomic weights, and therefore between the polymer and the gold. Figure 4.a illustrates an

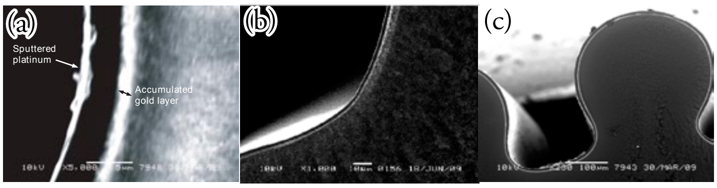


Figure 4 - (a) Illustration of the skin layer thickness determination method using gold colloids. (b) Skin layer of a hollow fiber spun from a polymer dope close to the cloud point. (c) Skin layer of a hollow fiber spun from a polymer dope further from the cloud point.

example of an image obtained by this technique. It was observed during our studies that hollow fibers with microstructured outer surfaces which are spun from polymer dopes very close to the could point (i.e. that coagulate almost immediately upon entering the nonsolvent bath) have homogeneous skin layer thickness all throughout the surface (Figure 4.b), while dopes further away from the cloud point tend to show thinning of the skin layer in the grooves of the structure (Figure 4.c)

The microstructure on the membrane surface affects the concentration polarization and consequent fouling behavior during filtrations with these membranes. In this study, the fouling behavior of microstructured membranes in dead-end, cross-flow and submerged-aerated operations was investigated using different techniques, such as flux stepping/cycling, online NMR imaging and direct visual observation. Online NMR imaging of dead-end silica filtration revealed that silica sols with different size and ionic medium deposit in different ways on the fibers (Figure 5). The difference between the deposition patterns was attributed to the different concentration profiles in the polarization layer that forms near the membrane surface. The larger silica particles in higher ionic strength medium which form high-resistance concentration polarization layers are thought to cause an imbalance between the resistance in the grooves and fins of the microstructured fibers, which leads to the distribution of the flow to equalize the resistance throughout the surface. On the other hand, with smaller silica particles that have polarization layers of lower resistance, particle deposition primarily occurs in the grooves of the structure. In flux stepping experiments with silica, the fouling is found to be fully reversible for both structured and round fibers, whereas with sodium alginate the structured fibers showed better fouling reversibility.

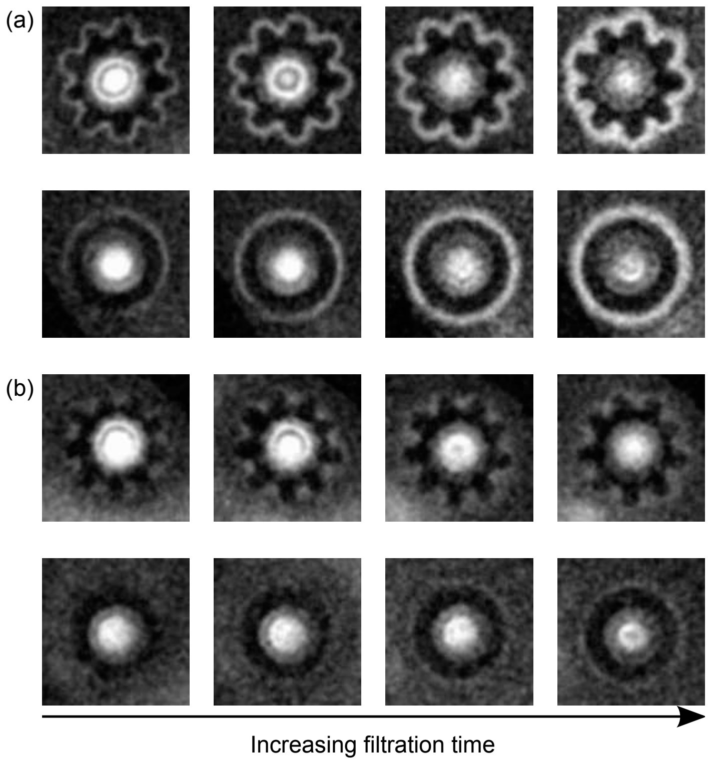


Figure 5 - Online NMR images of the cross sections of structured and round hollow fibers during dead-end silica filtration. (a) Silica sol with larger particle size and higher ionic strength medium. (b) Silica sol with smaller particle size and lower ionic strength medium.

In cross-flow and submerged-aerated systems, twisted fibers were used in addition to the structured and round fibers. These fibers were made by twisting individual structured fibers around their axes. In both systems, twisting reduced fouling on the fibers. In cross-flow filtrations with yeast particles, mostly higher critical fluxes were obtained with twisted fibers compared to structured and round fibers. Direct visual observation of the fiber surfaces during filtration revealed that with twisted fibers deposition on the fins of the structure is slower than that on the grooves of the twisted fibers, the fins and grooves of the structured fibers and on the whole surface of the round fibers (Figure 6). This reduced deposition is attributed to secondary flows which occur due to the twisted surface.

Figure 6 - Direct visual observation of the surface of hollow fibers during cross-flow yeast filtration. (a) Fin of the twisted fiber. (b) Fin of the structured fiber. (c) Round fiber.

While most of this study focuses on microstructured hollow fibers, a small part of it is on polymeric microsieve fabrication via PSµF. Two aspects of microsieve fabrication are addressed: The downscaling of the microsieve perforation size by solvent shrinking, and the effect of mold design on the ease of release of the microsieves from the molds. It was shown that by placing the microsieves in acetone and acetone-NMP mixtures the perforation size can be decreased by up to 70%. Using molds with pillars spaced in a circular arrangement rather than the standard square array have proved to make the release of the microsieves from the molds much easier.

For more information, please contact Rob Lammertink (r.g.h.lammertink@utwente.nl, +31 53 489 4798).

Publication award for Kitty Nijmeijer

During the 49th Dies Natalis (anniversary) of the University of Twente on November 26, 2010, Dr. Kitty Nijmeijer received the Prof. de Winter Prize of the University of Twente. The Prof. de Winter Prize is an annual publication award of € 2500 for a female top scientist.

Kitty is associate professor in Membranes for Energy Applications, and she received the award for her work on the generation of electrical power from the mixing of sea and river water, a process called reverse electrodialysis or Blue Energy. The paper describes a strategy to improve the power output directly obtainable from RED with at least a factor 3 by the use of ion conductive membrane spacers. The work has been performed in IMPACT, the research institute for Energy & Resources.

Reverse Electrodialysis can be applied everywhere where river water flows into the sea, to generate sustainable energy. It uses the free energy of mixing of two solutions of different salinity (e.g. river and sea water) to generate power (Figure 1).

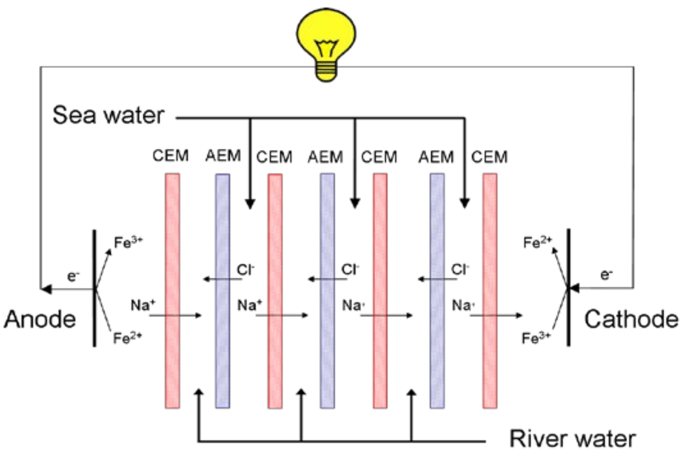


Figure 1 - Schematic representation of reverse electrodialysis.

In RED, a concentrated salt solution and a less concentrated salt solution are brought into contact through an alternating series of anion exchange membranes (AEM, transport of Cl^-) and cation exchange membranes (CEM, transport of Na^+). At the electrodes a redox couple is used to mitigate the transfer of electrons.

Theoretically, salinity gradient energy has a global potential of 2.6 TW as renewable energy source. Although the theoretical potential is high, the practical power output obtained is limited yet due to concentration polarization phenomena and spacer shadow effects. The work shows that non-conductive spacers, which have been used so far, block the ionic transport in RED and reduce the net power output obtainable dramatically. When the non-conductive spacers are replaced by a conductive alterative, a three times increase in power output is obtained, which brings RED as source for sustainable energy generation close to practical implementation.

Kitty's area of expertise is the design and application of Membranes for Energy Applications. More specifically, it covers gas and vapor separations and electro membrane processes. Next to Blue Energy, she works on e.g. water vapor removal, CO_2 capture, olefin/paraffin separation, the separation of chemical building blocks from bio-renewable feedstock and membranes for biorefinery concepts.

For more information, please contact Dr. Kitty Nijmeijer (d.c.nijmeijer@utwente.nl; phone: +31 53 489 4185)

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Charged porous membrane structures for separation of biomolecules

Bioseparations require different techniques than those used in traditional chemical industries. Biomolecules, the organic molecules produced by a living organism are labile and are generally processed at mild conditions. When heated or placed in environment of extreme pH for example, they change their structure, lose their function and are eventually destroyed.

As most of the biomolecules are charged, using a charged membrane for the separation provides improvement of the separation selectivity. A positively charged membrane gives higher retention of a positively charged biomolecule than a neutral or negatively charged membrane of the same pore size. The most applicable group of biomolecules to be used with charged membranes are proteins and this thesis is focused on them. The net charge of a protein depends on the sum of positive and negative charged amino acids, which is a function of the solvent pH. Charged proteins can be fractionated based on charge, even though they have similar sizes. The separation of biomolecules with charged membranes requires optimization of various process parameters like pH, ionic strength of the buffer solution as well as if possible tailoring the membrane and protein charge.

This thesis presents various techniques to produce charged membranes. In all cases polymeric porous fiber membranes are produced via the immersion precipitation wet-dry spinning and tested for separation of biomolecules.

Chapter 2 and 3 focus on development of ultrafiltration membranes. In both chapters a novel technique of introduction a charge onto the membrane surface by dissolving a polyelectrolyte in the bore liquid is applied. In Chapter 2, a negatively charged, polyimide P84-based membrane is produced by dissolving a sulphonated poly (ether ether ketone) (SPEEK) in the bore liquid, which is deposited on the bore surface of the hollow fiber during the membrane formation. The zeta-potential of the lumen surface of such a membrane is almost three times higher than of the pure P84 membrane. Filtration of a mixture of proteins with similar molecular weights, bovine serum albumin and hemoglobin, but differing in the electrostatic properties, through a P84/SPEEK membrane results in selectivity of over 210 in comparison to selectivity of 60 obtained with the pure P84 membrane at the same pH. Such a high selectivity is due to the electrostatic interactions membrane – protein which can be tuned with pH. This in-line one-step spinning method of introduction charge into the membrane can be an alternative for blending or co-extrusion, because it has the advantages of reduced amount of the required polyelectrolyte and the simplicity of fabrication. The P84/SPEEK membranes might find application not only for the separation of biomolecules, but also for salt rejection and other areas of membrane technology where charged solutes need to be separated.

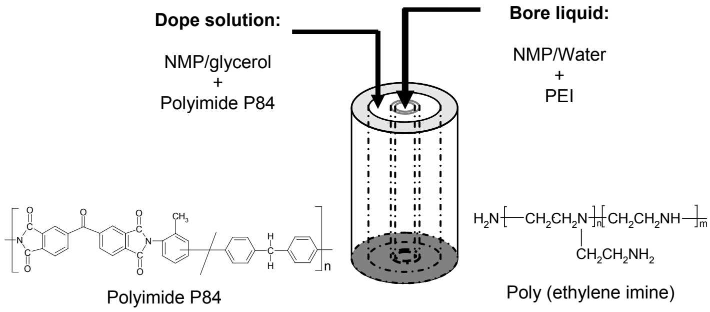


Figure 1 - Schematics of the spinneret and the compositions of polymer dope and bore liquid in the concept of "chemistry in a spinneret".

Chapter 3 also explores the technique of dissolving a polyelectrolyte in the bore liquid, but here, this polyelectrolyte (polyethyleneimine, PEI) is at the same time a crosslinking agent for the P84 membrane forming polymer (Figure 1). During this process, interplay of membrane formation by phase separation and crosslinking occurs. We demonstrate that this interplay can be controlled by the ratio solvent/nonsolvent in the bore liquid, shell liquid, and/or in the polymer solution. Depending on the composition of the bore liquid, two different types of membranes can be produced: either a completely crosslinked, not soluble in N-methylpyrrolidone and porous ultrafiltration fiber, or a porous fiber with a crosslinked dense inner layer selective for gases (Figure 2). In fact, by adding PEI into the bore liquid we can tailor the membrane morphology, chemistry, charge and hydrophilicity. The porous charged P84/PEI membrane has higher selectivity for the separation of the protein mixture, bovine serum albumin and hemoglobin in comparison to pure P84 membrane due to the positive charge of the crosslinked membrane. This new method of fabricating composite hollow fiber membrane is simpler, less time consuming, less expensive and more environmental friendly in comparison to other multi-step techniques. It may open perspective towards fabrication of novel membranes not only in the area of bioseparations, but also in gas separation and nano- and ultrafiltration, especially in harsh solvent environments.

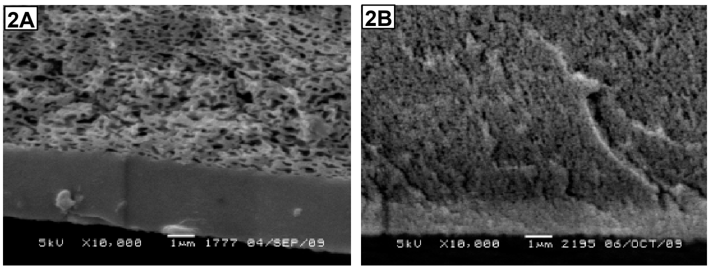


Figure 2 - SEM images of the bore side of the hollow fiber membranes produced with bore liquid composed of: (A) 20 % PEI, 70 % NMP, 10 % H_2O, (B) 10 % PEI, 10 % NMP, 80 % H_20.

Membrane chromatography is the next membrane separation technique presented in the thesis (Chapter 4). This method is based on the adsorption of biomolecules onto the mixed matrix hollow fiber membranes. The charge is introduced into the membranes by dispersing negatively charged particles in the P84 matrix polymer. The novelty is that the membranes are made solvent resistant by crosslinking them with ethylenediamine and for the first time applied for the adsorption of biomolecules from organic solvents. In aqueous solutions, the membranes have high adsorption capacity of bovine serum albumin and lyzosyme due to the electrostatic interaction between the positively charged protein and negatively charged membrane. However, the adsorption of lyzosyme from dimethyl sulphoxide and cholesterol from N-methylpyrrolidone is significantly lower. In these systems, the adsorption is due to the hydrophobic interactions (rather than the electrostatic interactions) and is lowered by the membrane swelling. The advantage is, however, the better accessibility of the particles in the membrane in comparison to the suspension of particles, which undergo aggregation in organic solvents. We show the proof of concept of the solvent resistant mixed matrix adsorber membranes and we suggest that for further improving this technology, various other types of particles as well as other target molecule/solvent systems should be considered.

Capillary electrochromatography (CEC) is the last technique presented in this thesis as a method for biomolecule separation. In fact, Chapter 5 describes application of membrane technology for fabrication of a stationary phase as a column for this hybrid analytical separation technique. Different polymers are processed either via immersion precipitation spinning into: (i) full fibers being a blend of polyimide P84 and SPEEK, (ii) small-bore P84 fibers coated with SPEEK by dissolving it in the bore liquid (technique developed in Chapter 2), (iii) mixed matrix full fiber made by incorporating negatively charged particles into poly(ether sulphone) matrix, or via phase inversion in-situ as (iv) monoliths of P84 or poly(methyl methacrylate). All produced membranes are evaluated in terms of the morphology, zeta-potential and performance in the CEC mode to estimate the electroosmotic flow, selectivity and efficiency. The proof of concept is shown - inorganic compounds as well as large proteins like bovine serum albumin pass through the porous charged membrane structure under application of external electrical field and are detected on-line in form of peaks on the electropherogram. The separations have poor reproducibility, selectivity and efficiency due to the inhomogeneous membrane morphology, membrane swelling and rather large membrane dimensions resulting in overheating. Further optimization of these membrane stationary phases should result in improvement of the column characteristics.

For more information, please contact Dimitris Stamatialis (d.stamatialis@utwente.nl, +31 53 489 4675).

Ph.D. Defenses

January 28, 2011	February 4, 2011	February 25, 2011
Karina Kopec	Srivatsa Bettahalli	Abdulsalam Al-Hadidi
Charged Porous Membrane Structures for Separation of Biomolecules	Membrane Supported 3D Scaffold Architectures for Tissue Engineering	Limitations, Improvements, Alternatives for the Silt Density Index

Hollow fiber membranes for tissue engineering

Name
Nazely Diban

Origin
Spain

Contact
0031 (0) 53 489 4012
n.dibanibrahimgomez@utwente.nl

Nazely Diban obtained her MSc in Chemical Engineering at the University of Cantabria (Spain) in 2003, after an Erasmus granted period in the Dust Explosions group at the TU Delft (The Netherlands) where she developed the final MSc project entitled "Removal of Hydrogen from a Nitrogen Stream by means of Adsorption". She received the PhD degree in Chemical Engineering in 2008 developed in the Department of Chemical Engineering and Inorganic Chemistry of the University of Cantabria in Spain defending the thesis entitled "Aroma compounds separation during fruit juices and beverages processing". During the PhD period she made a short stage research collaboration with the Institut National de la Recherche Agronomique (INRA) in Thiverval-Grignon (France). In September 2010, she joined the Membrane Science and Technology group at the University of Twente for a 1-year postdoctoral position funded by the Spanish Ministry of Education focused on the research topic "Development of biodegradable hollow fiber membranes for tissue engineering".

Removal of trace organic contaminants

Name
Joris de Grooth

Origin
The Netherlands

Contact
0031 (0) 53 489 3674
j.degrooth@utwente.nl

Joris de Grooth finished his MSc. degree in Chemical Engineering at the University of Twente in 2008. During his master he focused on analytical, organic and polymer chemistry. Part of his master was an internship at GE Plastics, were he worked on the influence of organic impurities on the preparation of polycarbonate and the properties of the obtained polymer. During his final master assignment at the Westfälische Wilhelms-Universität in Münster he worked on nanoparticle bases immunoassays. After his master, Joris started working at Norit X-Flow. Here he works on both process and product innovation at the R&D department. Now, after almost 3 years at Norit, he will combine his work at Norit X-Flow with a PhD in the Membrane Technology Group. The project is a collaboration between the University and Norit X-Flow. The focus of the research is the development of novel membrane concepts for the removal of trace organic contaminants. The project will combine the academic expertise of the Membrane Technology Group with the practical know-how of Norit X-Flow.

Catalytic membrane reactors for water vapor removal from industrial process streams

Name
Harro Mengers

Origin
The Netherlands

Contact
0031 (0) 53 489 2107
h.j.mengers@utwente.nl

Harro Mengers was born in the Netherlands and achieved in 2008 his Bsc. degree at the University of Twente with a research thesis on "CO_2 removal in a membrane contactor with aqueous sarcosine salt solution as absorption liquid". After his Bsc. degree Harro Mengers started the Master Chemical Engineering at the University of Twente, specialization in Process Technology. He achieved his Msc. degree in November 2010 with the title "Integrating electrodialysis and enzymatic conversion for the isolation acidic amino acids".

In December 2010, Harro Mengers started his PhD. The focus of his PhD, which focuses on the removal of water vapor from industrial process streams using catalytic membrane reactors.

New people

High temperature proton conductor

Name
Weihua Zhou

Origin
China

Contact
0031 (0) 489 2859
w.zhou-2@utwente.nl

Weihua Zhou finished his Ph.D. project in Inorganic Membrane group, University of Twente in August 2010. His Ph.D. project focused on the solid acid proton conductors (e.g. $KH(PO_3H)$ and $CsH(PO_3H)$) that work at the mid-temperature condition 130-160 °C. From September 2010, he work as a postdoctoral researcher in the same group. The current research concentrates on preparing and investigating a new kind of catalysts for methane coupling, which will be used as the anode of high temperature fuel cell and hydrogen pump at 800-1000 °C. This new project is a collaborative project from Applied Catalysis European Network.

Silica on a roll

Name
Emiel Kappert

Origin
The Netherlands

Contact
0031 (0) 53 489 2859
e.j.kappert@utwente.nl

Emiel Kappert obtained his MSc degree in Chemical Engineering at the University Twente. During his studies he has been working at the Potchefstroom University in South Africa for his bachelor's assignment; furthermore, he spend two years leading study association Alembic. In October 2010, Emiel graduated in the research group of Inorganic Membranes on the 'Rapid processing of inorganic membranes'. Although specialised in materials science, his research interests are broad and includes topics like process engineering and fluid dynamics. The PhD project will be a continuation and extension of the research started during the master's assignment.

Ph.D. Vacancies

Novel materials for gas separation membranes

Currently the department Aerospace Engineering of Delft University is collaborating with the Membrane Technology Group of the University of Twente on a project in which we explore novel, high-performance polymer architectures based on poly(ether-imide) and poly(ether-amide) chemistries as potential materials for high-pressure gas separation applications. In this project we will design and synthesize new monomers and polymers, investigate their thermo-mechanical properties and study their usefulness as films for a variety of gas separation applications (e.g. separation of CO_2/CH_4 and olefin/paraffin mixtures). You will not only be in charge of polymer synthesis and polymer characterization but you will also assist with inventorying the membrane properties, which will be done in close collaboration with the UTwente.

We are looking for highly motivated and enthusiastic researchers with an MSc degree, preferably in the field of organic chemistry or polymer synthetic chemistry. Experience with polymer characterization (DSC, TGA, DMTA, XRD, GPC) and polymer film processing techniques is a definite advantage.

We prefer candidates with a good team spirit, who like to work in an internationally oriented environment. Fluency in English is a requirement. An interview and a scientific presentation will be part of the selection procedure. Location of the position is Delft University.

For more information about this position, please contact Prof. Theo Dingemans (TU Delft, phone: +31 (0)15-2785420; t.j.dingemans@tudelft.nl) or Dr. Kitty Nijmeijer (UTwente, phone: +31 (0)53-4894185; d.c.nijmeijer@utwente.nl).
Interested candidates can e-mail a detailed CV including an up-to-date list of publications and contact information for 3 references, along with a letter of application to Prof. Theo Dingemans, mentioning the vacancy number (LR10-01).

Ph.D. Vacancies

Selective ion transport in ionophore based membranes

Within the Membrane Science & Technology group (www.membrane.nl), in close collaboration with Wetsus, centre of excellence for sustainable water technology (www.wetsus.nl) we have a vacancy for a Ph.D. position on:

'Selective ion transport in ionophore-based membranes'.

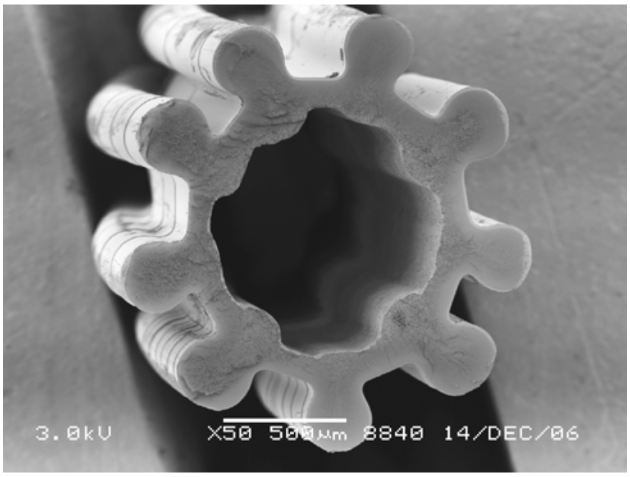
Selective removal of specific ions from solutions containing ions equal in size and charge is not trivial, but nevertheless of industrial importance. Examples are the selective removal of Li+ from seawater or the recovery of sulfate from wastewaters in the diary industry where huge amounts of sulfuric acid are used to coagulate caseine present in milk. The project intents to design such ion-selective membranes able to discriminate between ionic species of equal valence and similar size, based on ionophores as primary building blocks. Examples of ionophores are chemically synthesized crown ethers. Depending on the number of coordinating oxygens and the ring size, crown ethers express a high affinity for one particular ionic species. The project covers the design, characterization and application of such ionophore-based membranes and aims to get fundamental understanding in the binding and release mechanisms and transport phenomena of ions through these membranes. We are looking for highly motivated and enthusiastic researchers with an MSc degree in chemistry, chemical engineering, material science or a related topic, with adequate experimental and theoretical skills. We prefer candidates with a good team spirit, who like to work in an internationally oriented environment. Fluency in English is a requirement. An interview and a scientific presentation will be part of the selection procedure.

Interested candidates can send their motivation letter, CV (including references) and list of courses and grades to Dr. Kitty Nijmeijer (d.c.nijmeijer@utwente.nl; phone: +31 53 489 4185).

Dehydration of compressed fluids

Compressed fluids, such as supercritical carbon dioxide, can be used for effective and benign drying of solid products. Economic viability of these drying processes is hampered by the energy intensive regeneration of the high pressure medium. In this project membrane technology will be developed for energy efficient removal of water from high pressure fluids.

For more information, please contact Dr. Nieck Benes (n.e.benes@utwente.nl; phone: +31 53 489 4288)



Hybrid silica membranes for affinity based separation

Recently, is has been demonstrated that sol-gel derived micro-porous hybrid silica membranes (HybSi®) have superior hydrothermal stability in dewatering processes, as compared to other sol-gel derived membranes. This project involves a study of the applicability of hybrid silica membrane materials in affinity-based separations. Aim is to introduce functional groups via sol-gel processing of suitable precursors and precursor mixtures.

For more information, please contact Dr. Nieck Benes (n.e.benes@utwente.nl; phone: +31 53 489 4288)

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