2011 summer

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

Tenure tracker on porous systems for the separation of complex mixtures

Míriam Gironès

Since May 1st the MST group has a new staff member and Assistant Professor, Dr. Míriam Gironès. Míriam, who holds a tenure track position, will be in charge to expand and establish MST's research lines regarding porous systems for complex liquid separations and support ongoing activities related to current research performed at the MST group. "The road ahead is definitely challenging", she says, "but I am truly honored to be able to join the MST team and have the opportunity to bring my ideas to life in such an excellent environment".

Prior to her current position she served as Project Leader R&D and Business Developer at Nanomi B.V. (a Dutch company specialized in the development of microspheres for the life sciences, enabled by Microsieve emulsification). For the last five years she was involved in the formulation and development of monodisperse microspheres for drug delivery, diagnostics, imaging, etc. for renown pharmaceutical, biotech companies and institutions worldwide. She was responsible for the supervision of privately and publicly funded R&D projects and managing personnel and resources. In her role as Business Developer she was involved in the acquisition of new customers/partners, project evaluation and feasibility, writing project proposals and establishing a broad network of contacts in the field.

Míriam has always been closely related to the MST group, also during her period in industry. However, her relationship with the group goes far back in time. She first came into contact with membranes and the MST group in 1999 during a short practical internship. After obtaining her MSc. degree in Chemistry from the University of Girona (Spain) she rejoined the group as a Research Assistant in late 2000, working on mixed matrix membranes for protein recovery until 2001. She obtained her PhD degree in 2005, with a thesis entitled "Inorganic and polymeric microsieves, strategies to reduce fouling". In her work she characterized inorganic microsieves, manufactured and characterized polymeric microsieve membranes and investigated their filtration behavior and several strategies to reduce fouling (backpulsing, surface modification, etc.). In 2006 she worked as a Postdoctoral researcher on the development of micropatterned biodegradable polymeric scaffolds for tissue engineering.

Within her tenure track position Míriam will be responsible for research, educational and organizational tasks. The ultimate goal will be the establishment of a well-defined research line on porous systems through a multidisciplinary approach based on her background and expertise. Her research goals will be related to the design of porous systems to separate complex multicomponent mixtures in pharmaceutical, food, beverage and diagnostics applications, among others (see Figure 1).

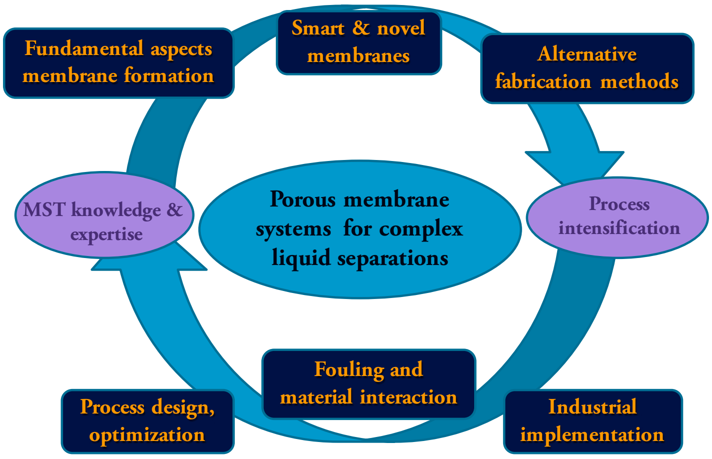


Figure 1 - Research vision.

Without forgetting the fundamental aspects of membrane formation other approaches that will help create membranes

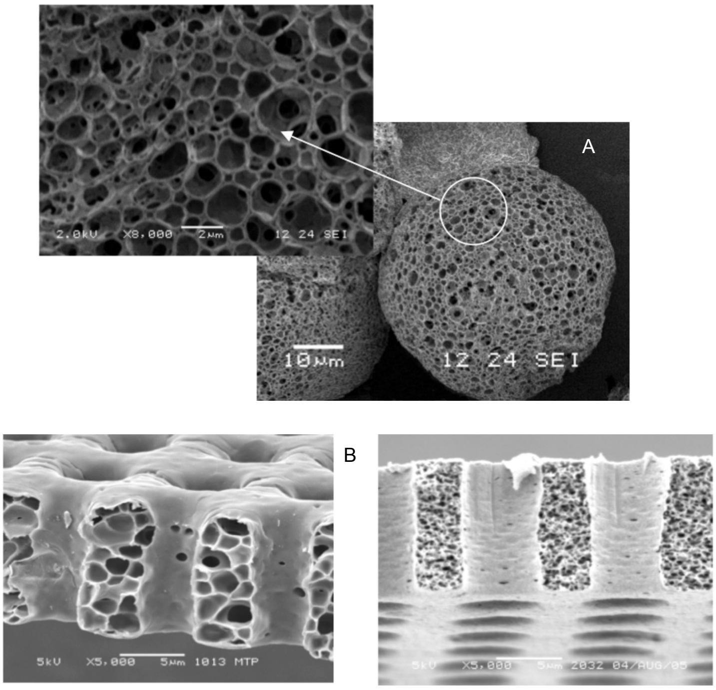


Figure 2 - Porosity and pore morphology, both crucial aspects tunable for achieving optimal membrane performance. Figure A shows highly porous microspheres fabricated by phase separation (Courtesy of Nanomi B.V.) and Figure B shows polymeric microsieve membranes, fabricated by Phase Separation Micromolding and variable internal porosity[1].

with outstanding and predictable separation behavior and throughput in life sciences-oriented applications will be considered. Important subjects will be tuning the material properties and structure (e.g. pore morphology and porosity, see Figure 2), develop functional materials (e.g. affinity separations of biomolecules) and create new and/or improved processes (e.g. faster processes, higher yields, less fouling, etc.). Other aspects related to process design and industrial implementation, such as scale-up of novel membrane fabrication methods, will also be investigated.

[1] Gironès M. (2005), Inorganic and polymeric microsieves, strategies to reduce fouling. Ph.D. Thesis, University of Twente, The Netherlands, ISBN: 90-365-2289-7.

Register now at:

icom2011.org/call-for-papers/
registration-3

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

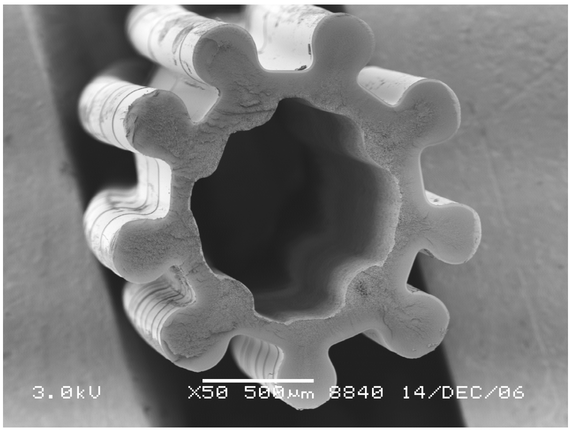
ICOM 2011 covers the multidisciplinary chain of membrane science and technology ranging from molecule to process. It addresses both fundamentals as wells as the application of membranes. The conference will have almost 400 oral presentations and two poster sessions.

Network Young Membrains (NYM 13)

Network of Young MemBrains (NYM) 2011 will be hosted by Membrane Technology Group of the University of Twente. It will be organized in Enschede, The Netherlands, from July 21 until July 23, 2011. NYM 2011 is sponsored by European Membrane Society (EMS).

Pre-conference workshops

As a part of the technical program for ICOM 2011, an international group of membrane experts will conduct four 1-day workshops in key membrane technology areas. Topics to be covered are hydrodynamics and module design (Prof. Thomas Melin, RWTH Aachen University, Germany), membrane bioreactors (Prof. TorOve Leiknes, NTNU Norwegian University of Science and Technology, Trondheim, Norway), desalination (Dr. Pierre Aimar, Université de Toulouse, Toulouse, France) and membrane gas separation for industrial flue gas (Ir. Paul Raats, KEMA Nederland B.V., Arnhem, The Netherlands). For more information, please visit http://icom2011.org/meeting-info/workshops



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

June 1, 2011 Conference program available
July 1, 2011 Abstracts available on website
July 21-23, 2011 Network Young Membrains
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.

EVONIK INDUSTRIES · sartorius stedim biotech · MERCK MILLIPORE · Vitens · Pentair X-Flow · EMS European Membrane Society · Solvay Specialty Polymers · SOLVAY

For sponsoring opportunities, please contact Dr. Kitty Nijmeijer (e-mail: d.c.nijmeijer@utwente.nl; Phone: +31 53 489 4185)

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
Kitty Nijmeijer
Enver Güler
membrane@utwente.nl
www.membrane.nl

Study Tour 2011

The study tour of the Membrane Technology Group is a cyclic event organized every few years. Its purpose is to develop and strengthen the relationships between the industry or research institutes and our group. This year's edition lasted the whole week and enabled to review quite a variety of different membrane science and technology related facilities.

The tour kicked off with a visit to the Institute of Aachener VerfahrensTechnik (AVT) - Chemical Process Engineering at RWTH Aachen (Germany). The introductory lectures by Prof. Matthias Wessling (RWTH) and Prof. Arian Nijmeijer (Inorganic Membranes, UTwente) introduced the general research activities of both groups. Afterwards PhD students of both groups gave more detailed presentations on their specific research topics. The visit included a facility tour guided by the members of AVT, which helped to produce a stimulating atmosphere for many scientific discussions.

The second destination was Parker Filtration and Separation B.V. located in Etten-Leur in the south of the Netherlands. The company is specialized in the production of membranes and modules for gas separation. Dr. Maarten Roks welcomed us and gave a detailed overview of the company's portfolio. The facility tour at Parker was a very nice occasion to get an overview of the full production process ranging from hollow fiber membrane spinning and production towards module development, production and performance testing.

The Centre of Surface Chemistry and Catalysis at Leuven University in Belgium was the third destination of the tour. Once again the visit was opened with introductory lectures given by Prof. Ivo Vankelekom (KU Leuven) and Dr. Kitty Nijmeijer (Membrane Science & Technology, UTwente), followed by specific presentations of the PhD students. An extensive lab visit completed the visit, which provided an impressive picture of membrane research performed in Leuven.

The stay at Leuven was combined with a visit to the Rubens (the painter) Museum in Antwerp, which was a nice chance to escape from the world of science and enter the realms of 17th century paintings.

The fourth day of the tour was spent at Flemish Institute of Technological Research – VITO in Mol, Belgium. Dr. Inge Genné welcomed our group and presented the research activities of VITO. This was followed by a presentation of Dr. Antoine Kemperman (Membrane Science & Technology, UTwente) and presentations of researchers from both groups. After an impressive labtour through the facilities of VITO, which range from lab scale equipment towards large scale pilot testing facilities, researchers from both groups had the chance to share ideas during a drink with Belgium beers.

A visit to Evonik Industries in Marl, Germany concluded this study tour. The visit was an interesting occasion to get a glimpse of large-scale industries. A bus tour at the facilities at the industrial park in Marl provided to opportunity to see one of the largest chemical parks in Germany. Dr. Jörg Balster (former PhD student at the Membrane Science & Technology Group of the University of Twente) shared some of the developments on solvent resistant nanofiltration.

Overall the study tour was an inspiring event showing the multidisciplinary character of Membrane Science and Technology ranging from materials science and membrane design at lab scale towards large-scale membrane module production and process synthesis.

Limitations, improvements and alternatives for the silt density index

Reverse osmosis (RO) and nanofiltration (NF) membrane systems are widely used for the desalination of water. However, fouling phenomena in these systems remain a challenge. Four different fouling types can be identified: 1) Particulate fouling due to suspended and colloidal matter, 2) Biofouling due to adhesion and subsequent growth of bacteria, 3) Organic fouling due to organic compounds and 4) Scaling due to precipitation of sparingly soluble compounds. The Silt Density Index (SDI) test is a widely-accepted method for estimating the rate at which colloidal and particle fouling will occur in RO or NF water purification systems.

During the SDI test the time required to filter a fixed volume of water through a standard 0.45 μm microfiltration membrane at a constant given pressure is measured. The difference between the initial time and the time of a second measurement after 15 minutes (after silt built-up) results in the SDI value. The ASTM describes this test as a standard test for RO fouling potential due to particles. According to the standard, the applied pressure is 207±7kPa (30±1psi). The water temperature must remain constant (±1°C) throughout the test.

From a practical point of view, the SDI for fine hollow fiber RO feed water preferably must be lower than 3. A pretreatment method such as UF therefore has to guarantee an RO feed water with an SDI <3. An SDI test is one of the criteria in designing new desalination plants and has to be performed on the RO feed water. The SDI is a useful parameter to monitor the efficiency of the RO pretreatment in removing the particles presents in the raw water. The main advantage of the SDI test is that the test is simple to execute, even by non-professionals. The SDI has an economical value since it is mentioned as a condition in the pretreatment process contract.

Although the SDI test is widely used, there is growing doubt about the value of the SDI test as a predictive tool for RO membrane fouling. These doubts consist of two factors: 1) the relation between the SDI value and the performance of the RO unit, and 2) the reproducibility and accuracy of the SDI test.

Limitations: The influence of membrane properties on the SDI value was investigated. Moreover, the variation in membrane properties was studied in order to understand the difficulties in SDI reproducibility. Eight commercial '0.45 μm' membrane types made of different materials and by different manufacturers (PVDF, PTFE, Acrylic copolymer, Nitro Cellulose, Cellulose Acetate, Nylon 6,6, and Polycarbonate) were used to measure the SDI.

Three samples were randomly chosen from each membrane type (out of the same lot), and several membrane properties were studied (pore size distribution, pore shape, surface and bulk porosity, thickness, surface charge, contact angle and surface roughness). SDI values for an artificial feed, composed of a solution of α – alumina particles of 0.6 μm size, were determined. The characterization of these membranes shows variations between the membranes used in this study (M1-M8), and within a batch of one membrane type. Substantial differences were found in the SDI values for different types of membrane filters used (Fig.1). These variations can be attributed to differences in properties of the membranes used.

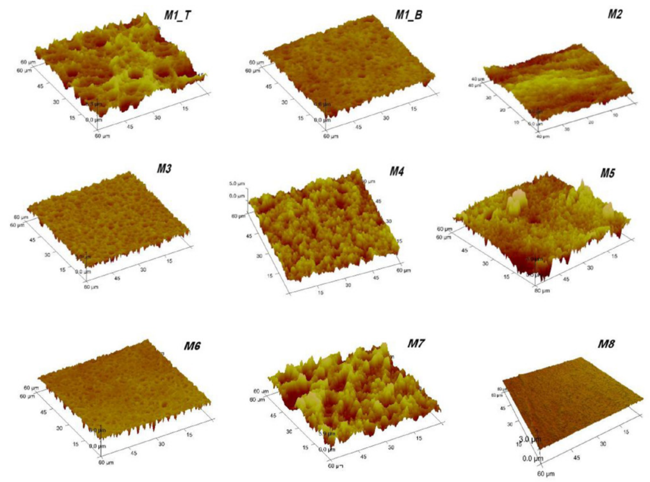


Figure 1 - AFM topographic images of membranes M1-M8.

Improvements: A mathematical relation between the SDI and a second filtration index, the MFI0.45, has been developed, assuming cake filtration as the dominant filtration mechanism during the tests. Based on the developed mathematical relation and experiments with a model feed water of α-aluminum particles (0.6 μm), it could be demonstrated that the SDI depends on pressure, temperature and membrane resistance. The effect of temperature and membrane resistance explains to a large extend erratic results from field tests. Existing mathematical models were further developed to study the effect of temperature and applied pressure on the SDI value under different fouling mechanisms. These fouling mechanisms are described by a relationship between the specific filtrated volume and the total resistance. A significant variation in the SDI value for the same water quality was observed mathematically as a result of differences in temperature and membrane resistance. The sensitivity of the SDI for variations in the testing parameters theoretically increases when the relation between and is stronger.

The SDI increases with an increase in the feed temperature and the applied pressure. The SDI value decreases when membranes with a high resistance are used (Fig.2). These effects were confirmed experimentally. Later on, the mathematical models were used to investigate the sensitivity of SDI for errors due to inaccurate lab or field equipment, systematic errors, and errors resulting from artifacts and personal observations and experience. These mathematical results were also verified experimentally.

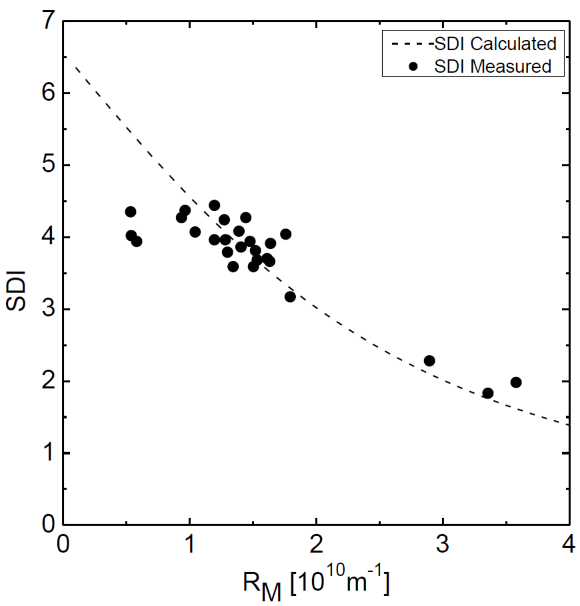


Figure 2 - SDI experimental and theoretical results as a function of the membrane resistance for different membranes. The experiments were carried out using a particles concentration of 4mg/L AKP-15 and a pressure difference of 207kPa.

Alternatives: Assuming cake filtration and 100% particle rejection, the SDI can be normalized to the SDI$^+$ based on the mathematical model (SDI-MFI0.45 relation). A line chart and slide wheel charts were developed to normalize SDI to SDI$^+$ for the testing conditions and the membrane resistance. A reference membrane resistance and reference testing conditions were proposed such as feed temperature and applied pressure.

A new fouling index was developed to estimate the RO feed fouling potential. The volume based SDI_v compares the initial flow rate to the flow rate after filtering the standard volume using MF membranes with an average pore size of 0.45 μm. The SDI_v has a linear relationship with the particle concentration if complete blocking is the dominant fouling mechanism during the test. The mathematical model shows that SDI_v is independent of the testing parameters T and dP and membrane resistance. The mathematical model and the experimental results show that SDI_v eliminates most of the above mentioned SDI disadvantages. The SDI_v is the second fouling index developed at the University of Twente, 30 years after the MFI0.45

The new indices SDI$^+$ and SDI_v were measured and the mathematical models were confirmed in a case study at the Evides UF/RO seawater desalination plant in the Netherlands (Fig.3). The use of different membrane materials for the SDI test resulted in significantly different numerical values for the same water quality. The effects of the individual membrane resistance and the testing condition parameters on SDI were properly incorporated in the SDI$^+$ values according to practice experiments. Consequently, the SDI results with different test membranes could be compared. We have proven that the SDI results under different testing conditions can be normalized to the reference parameters and therefore developed a more reliable filtration index. The plant was evaluated by performing the SDI, SDI$^+$ and MFI0.45 tests on-site under different operation regimes (coagulation, pH correction). It was found that the UF performance was good and SDI and MFI0.45 values were low. The MFI0.45 shows the same tendency as the SDI in most cases. Storing the RO feed for one night in the feed tank increases the fouling potential of the RO feed water.

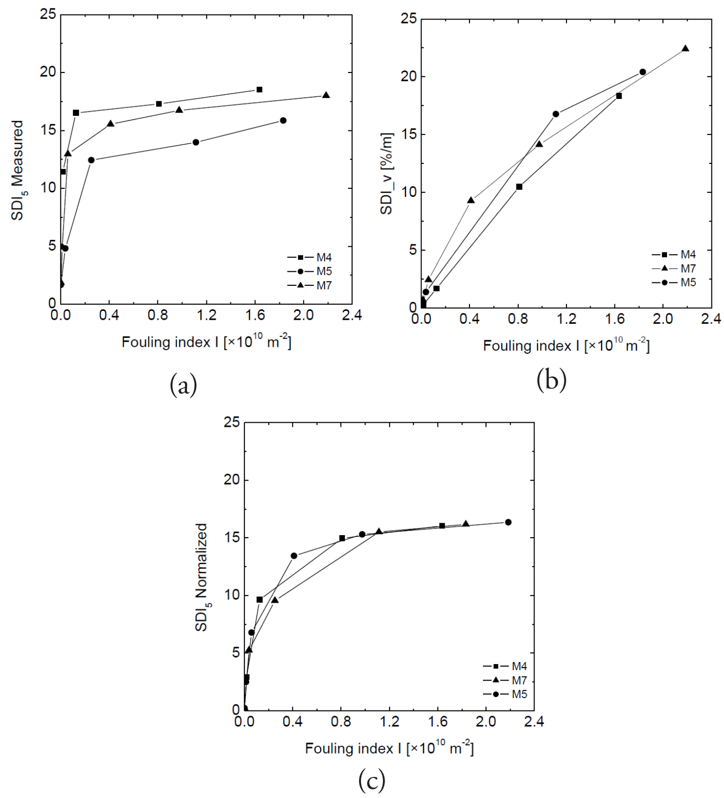


Figure 3 - (a) standard time-based SDI for 5 minutes elapsed filtration time (b) SDI_v values (c) time-based SDI normalized for the membrane resistance and the testing condition parameters (SDI$^+$).

Membrane runners participate in Batavierenrace

On May 7th the Membrane Alliance Twente upheld the tradition of participating in the annual Batavierenrace, under the appropriate name “Membrane Runners”. Ignoring the unjustifiably imposed time penalties the Membrane Runners ranked 140 place out of 300, the official ranking was 240.

With over 7500 participants the Batavierenrace is the world’s largest relay race, starting from Nijmegen and finishing in Enschede. The initial route was taken in 1972 following the journey of the Batavians in 50 BC, who sailed down the Rhine from Nijmegen to Rotterdam. Due to several reasons, the route has changed over the years. Presently, the race starts at midnight at the historic city of Nijmegen and finishes in the afternoon on the campus of the University of Twente, after a total distance of 177 km divided in 25 stages. While one person runs a stage, accompanied by a fellow team-mate on a bike, the rest of the team travels by van to the next waypoint. The teams in the race originate from many different countries and have a great variety of backgrounds. The highest ranking teams in the race consist of (semi) professional athletes.

This year, the “Membrane Runners” hosted researchers from research groups including Physics of Fluids, Physics of Complex Fluids, Catalytic Processes and Materials, and even from RWTH Aachen in Germany. All runners successfully completed their stage of the race. A subsequent culmination of blistering events was the ‘dinner with drinks’ in the garden of the family Benes in Oldenzaal, where complaints of muscle pain promptly transformed into grandiloquence and promises of participation in the next Batavierenrace.

Expectantly, the Membrane Runners will keep with the tradition of participating in Batavierenrace in the coming years, uniting scientific and sportive spirit in team spirit.

This event would not have been possible without the financial support of our sponsors. The Membrane Runners would like to express their gratitude to: the European Membrane Institute Twente (EMI Twente), Vitens, and Gambro.

EMI Twente

GAMBRO

vitens

New people

Membrane dehydration of supercritical carbon dioxide streams

Name
Beata Koziara

Origin
Poland

Contact
0031 (0) 53 489 3474
b.t.koziara@utwente.nl

Beata Koziara graduated from Chemical Engineering in October 2008 with a binational Polish-German Master degree. She spent the first 4 years of her studies at the Cracow University of Technology and the last year at the Münster University of Applied Sciences, in the framework of an Erasmus Exchange Program, where she completed her final M.Sc. project entitled "Protein extraction from rapeseed meal". After graduation she continued to work at Münster University at the department of Inorganic Chemistry in the research group "Tailored Optical Materials".

In January 2011, Beata Koziara started her PhD studies in Membrane Science and Technology Group at the University of Twente focusing on the dehydration of supercritical carbon dioxide using water selective membranes.

Fouling removal by nucleated CO_2 bubbles

Name
A.M.M. Al-hadidi

Origin
Yemen

Contact
0031 (0) 53 489 2107
a.m.m.al-hadidi@utwente.nl

Abdulsalam Al-hadidi graduated from Civil Engineering in July 1999. From 2000 to 2004 he worked for a rural water supply project in Yemen as a procurement officer. In 2006 he obtained his Master degree in Drinking Water Supply Technology at UNESCO-IHE, Delft, The Netherlands. The title of his M.Sc. project was 'Process evaluation of the Klazienaveen RO plant for the water supply company WMD'. In February 2011, Abdulsalam Al-hadidi obtained his Ph.D. degree in the Membrane Science and Technology Group of the University of Twente, The Netherlands. The title of his thesis was 'Limitations, Improvements, Alternatives for the Silt Density Index'. Prof. Walter van der Meer was his promotor. In March 2011, Abdulsalam started a post-doc project in the Membrane Science and Technology Group of the University of Twente. In this project he focuses on reducing fouling in spiral wound membrane modules for water purification by nucleating CO_2 bubbles in the feed spacer.

New membrane materials for water purification

Name
Szymon Dutczak

Origin
Poland

Contact
0031 (0) 53 489 2869
s.m.dutczak@utwente.nl

Szymon Dutczak was born in 1982 in Poland. He obtained his MSc in Applied Chemistry at the Cracow University of Technology and MSc in Chemical Engineering at the Fachhochschule Münster both in 2006. During his internship at Gambro Dialysatoren GmbH he was working on improvement of hollow fibre membranes for blood purification. The research work resulted in an MSc Thesis entitled "Super High-Flux Membranes". In 2007 he started his PhD in the Membrane Technology Group at the University of Twente. The topic of his research was "Nanofiltration hollow fibre membranes for non-aqueous application". The defense of his PhD thesis is planned for the end of 2011. In February 2011 he joined the European Membrane Institute (EMI) as a senior researcher. Currently he is working in close collaboration with industrial partners on development of new membrane materials for water purification.

Ph.D. Defenses

July 15, 2011
Schwan Hosseiny

Vanadium/air redox flow battery

November 11, 2011
Mayur Dalwani

Nanofiltration for extreme conditions

November 11, 2011
Szymon Dutczak

Solvent resistant nanofiltration membranes

Nature-inspired membranes

Safe and sufficient water relies on reliable and efficient separation processes. Over the past decades, membrane separations have emerged as the most viable solution to problems such as virus retention, ion retention (desalination) and ion separation (softening). Membranes used in these processes are characterized by an amorphous porosity, broad pore size distribution and low membrane porosity. Even though limited by these morphological constraints, ingenious process schemes on extremely large scale make membrane technology the technology of choice. It is highly desirable to discover new fabrication methods of new membrane materials that overcome those limitations. Filtration with high porosity, thin and isoporous membranes will be the technical solution of choice for particulate matter such as viruses and nano-particles.The aim of this project is the fabrication of bio-inspired nanoporous layers, for performing molecular separations such as desalination and disinfection. Two routes will be followed, the first aspires fabrication of supported isoporous 2D monolayer films, the second is directed at thin film enzyme activated composite 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).

Effect of nanoparticles in membrane filtration

Because of the increasing use of nanoparticles, they are ending up more and more in the environment and in drinking water sources. Not much is known on the toxicity of nanoparticles, nor on the effectiveness of membrane filtration in removing them. This project makes and inventory of which nanoparticles are present in natural water, their removal efficiency at drinking and waste water plants, the fouling behavior of feed waters containing nanoparticles and the analysis of the particles.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. Antoine Kemperman (a.j.b.kemperman@utwente.nl; phone: +31 53 489 2956).

Novel materials for gas separation membranes

Currently the department Aerospace Engineering of Delft University is collaborating with the Membrane Science & 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 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.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).

Publications

- Alhadidi, A., Kemperman, A.J.B., Blankert, B., Schippers, J.C., Wessling, M., van der Meer, W.G.J. Silt Density Index and Modified Fouling Index relation, and effect of pressure, temperature and membrane resistance (2011) Desalination, 273 (1), pp. 48-56. doi:10.1016/j.desal.2010.11.031
- Dutczak, S.M., Luiten-Olieman, M.W.J., Zwijnenberg, H.J., Bolhuis-Versteeg, L.A.M., Winnubst, L., Hempenius, M.A., Benes, N.E., Wessling, M., Stamatialis, D.Composite capillary membrane for solvent resistant nanofiltration (2011) Journal of Membrane Science, 372 (1-2), pp. 182-190. doi:10.1016/j.memsci.2011.01.058
- Çulfaz, P.Z., Haddad, M., Wessling, M., Lammertink, R.G.H. Fouling behavior of microstructured hollow fibers in cross-flow filtrations: Critical flux determination and direct visual observation of particle deposition (2011) Journal of Membrane Science, 372 (1-2), pp. 210-218. doi:10.1016/j.memsci.2011.02.002
- Dalwani, M., Benes, N.E., Bargeman, G., Stamatialis, D., Wessling, M. Effect of pH on the performance of polyamide/ polyacrylonitrile based thin film composite membranes (2011) Journal of Membrane Science, 372 (1-2), pp. 228-238. doi:10.1016/j.memsci.2011.02.012
- Bettahalli, N.M.S., Steg, H., Wessling, M., Stamatialis, D. Development of poly(l-lactic acid) hollow fiber membranes for artificial vasculature in tissue engineering scaffolds (2011) Journal of Membrane Science, 371 (1-2), pp. 117-126. doi:10.1016/j.memsci.2011.01.026
- Salamon, D., Chlup, Z., Lefferts, L., Wessling, M. Tailoring of free standing microchannels structures via microtemplating (2011) Materials Research Bulletin, 46 (4), pp. 505-511. doi:10.1016/j.materresbull.2011.01.005
- Truckenmüller, R., Giselbrecht, S., Rivron, N., Gottwald, E., Saile, V., Van Den Berg, A., Wessling, M., Van Blitterswijk, C. Thermoforming of film-based biomedical (2011) Advanced Materials, 23 (11), pp. 1311-1329. doi:10.1002/adma.201003538
- Luiten-Olieman, M.W.J., Winnubst, L., Nijmeijer, A., Wessling, M., Benes, N.E. Porous stainless steel hollow fiber membranes via dry-wet spinning (2011) Journal of Membrane Science, 370 (1-2), pp. 124-130. doi:10.1016/j.memsci.2011.01.004
- Kopeć, K.K., Dutczak, S.M., Wessling, M., Stamatialis, D.F. Tailoring the surface charge of an ultrafiltration hollow fiber by addition of a polyanion to the coagulation bore liquid (2011) Journal of Membrane Science, 369 (1-2), pp. 59-67. doi:10.1016/j.memsci.2010.11.060
- Çulfaz, P.Z., Wessling, M., Lammertink, R.G.H. Hollow fiber ultrafiltration membranes with microstructured inner skin (2011) Journal of Membrane Science, 369 (1-2), pp. 221-227. doi:10.1016/j.memsci.2010.11.063
- Kopeć, K.K., Dutczak, S.M., Wessling, M., Stamatialis, D.F. Chemistry in a spinneret-On the interplay of crosslinking and phase inversion during spinning of novel hollow fiber membranes (2011) Journal of Membrane Science, 369 (1-2), pp. 308-318. doi:10.1016/j.memsci.2010.12.010
- Çulfaz, P.Z., Buetehorn, S., Utiu, L., Kueppers, M., Bluemich, B., Melin, T., Wessling, M., Lammertink, R.G.H. Fouling behavior of microstructured hollow fiber membranes in dead-end filtrations: Critical flux determination and NMR imaging of particle deposition (2011) Langmuir, 27 (5), pp. 1643-1652. doi:10.1021/la1037734
- Ngene, I.S., Lammertink, R.G.H., Wessling, M., Van der Meer, W.G.J. Visual characterization of fouling with bidisperse solution (2011) Journal of Membrane Science, 368 (1-2), pp. 110-115. doi:10.1016/j.memsci.2010.11.026
- Reijerkerk, S.R., Nijmeijer, K., Ribeiro, C.P., Freeman, B.D., Wessling, M. On the effects of plasticization in CO_2/light gas separation using polymeric solubility selective membranes (2011) Journal of Membrane Science, 367 (1-2), pp. 33-44. doi:10.1016/j.memsci.2010.10.035
- Çulfaz, P.Z., Wessling, M., Lammertink, R.G.H. Fouling behavior of microstructured hollow fiber membranes in submerged and aerated filtrations (2011) Water Research, 45 (4), pp. 1865-1871. doi:10.1016/j.watres.2010.12.007
- Reijerkerk, S.R., Jordana, R., Nijmeijer, K., Wessling, M. Highly hydrophilic, rubbery membranes for CO_2 capture and dehydration of flue gas (2011) International Journal of Greenhouse Gas Control, 5 (1), pp. 26-36. doi:10.1016/j.ijggc.2010.06.014