North American Membrane Society

28th Annual Meeting

“Membrane Separations for Emerging Water, Energy, & Health Applications”

Overview of Technical Sessions

www.NAMS2019.org

May 11-15, 2019
Pittsburgh, PA
Wyndham Grand Pittsburgh Downtown
Membrane Materials for Organic Solvent Separations
Chairs: Steve White (steve.white@mtrinc.com) & Ryan Lively (ryan.lively@chbe.gatech.edu)
The session focuses broadly on liquid phase separations in organic media (e.g. organic solvent filtration, OSN/OSRO/OSFO, etc.). We are interested in topical areas ranging from novel materials for organic solvent separations, pilot/pre-pilot experiments, organic solvent transport in membrane materials, process systems analysis, new characterization techniques that are designed for probing membranes in organic media, etc.

Selective Polymeric and Mixed-Matrix Membrane Materials - Gas Separations
Chairs: Ben Sundell (benjamin.sundell@aramcoservices.com) & Zach Smith (zsmith@mit.edu)
Membrane-based gas separations are of interest for a variety of applications such as nitrogen generation, carbon dioxide removal from natural gas or flue gas, and olefin/paraffin separations. One approach to address these critical separation challenges is through the use of selective polymeric or mixed-matrix membranes. The rational design of the chemical and/or morphological structure of polymers is one way to surpass current performance and stability limitations. Additionally, incorporation of highly selective fillers, such as MOFs, ZIFs, COFs, zeolites, carbons, etc. can similarly enable improved performance. This session will highlight advances in the synthesis and design of polymers and inorganic materials to form pure polymeric and mixed-matrix membranes for gas separation applications.

Selective Polymeric and Mixed-Matrix Membrane Materials - Liquid Separations
Chairs: Dan Miller (danieljmiller@lbl.gov) & Baoxia Mi (mib@berkeley.edu)
We invite contributions to this session that explore the development of polymeric and mixed-matrix membrane materials for highly selective liquid separations. Innovative polymeric, inorganic, and hybrid membrane materials could enable separations that have heretofore been unachievable, are energetically intensive, or are cost prohibitive. Applications could include, but are not limited to, targeted contaminant removal from industrial or municipal wastewater, resource recovery, efficient organic separations, and desalination. The emphasis will be on materials synthesis and characterization, but contributions describing practical demonstration of highly specific separations are encouraged.

Ion-Exchange and Electrofunctional Membrane Materials
Chairs: Geoff Geise (gmg9j@virginia.edu) & Orlando Coronell (coronell@ad.unc.edu)
This session welcomes contributions that describe recent advances in both fundamental and applied understanding of membrane materials that function as ion exchange and/or electrofunctional materials. Such membranes are becoming increasingly important for desalination applications (e.g. membrane capacitive deionization or electrodialysis), energy technologies (e.g. batteries or reverse electrodialysis), and resource recovery. Furthermore, they traditionally have been used in other applications including water reuse, food processing, and the chloroalkali process. Contributions to this session should focus primarily on membrane materials and their properties (e.g. material synthesis, properties and/or performance characterization, and/or modeling) as opposed to the electro-membrane processes where these membranes are applied.

Catalytic and Responsive Membrane Materials
Chairs: Miao Yu (yum5@rpi.edu) & Ayse Asatekin (ayse.asatekin@tufts.edu)
This session will focus on membrane materials that incorporate additional functions, such as catalytic activity or responsiveness to external stimuli. Catalytic membrane materials can enable combining selective permeation with chemical conversion, for example, for degrading foulants. Responsive membrane materials can enable not only the tuning and control of membrane selectivity and permeability, but also fouling prevention and removal. Research presentations addressing these topics, or other related systems that leverage these properties for membrane applications, are invited to this session.
Membrane Materials, Continued

Bio-inspired and Biomimetic Membrane Materials
Chair: Chunlong Chen (Chunlong.Chen@pnnl.gov), Yair Kaufman (yairkau@bgu.ac.il) & Dibakar Bhattacharya (db@uky.edu)
The session will focus on new functional materials and scientific advancements that have potential to contribute to the field of bio-inspired and biomimetic membranes. We solicit papers relating to the topics (not limited to) such as: (1) self-assembly of bio-inspired/biomimetic membranes; (2) preparation and characterization of bio-inspired/biomimetic membranes; (3) material development advancements, including scale-up; and (4) demonstration of novel sensing or separation processes using bio-inspired/biomimetic membranes.

Membrane Material and Transport Simulation: Molecular & Process Modeling of Membranes
Chair: Chris Wilmer (wilmer@pitt.edu) & Abhishek Roy (ALRoy@dow.com)
Recent years have seen an explosion of papers on the subject of new membrane materials. However, the practical implementation of new membrane technologies requires understanding phenomena that span many time and length scales, and also take into account economic considerations. Computational modeling is a powerful tool that, when combined with a real understanding of process-application economics, can help predict useful direction for membrane researchers to pursue. This particular session calls for presentations on the following topics: (1) Atomistic/molecular modeling of materials and fluids in the context of membranes; (2) macroscale (or multiscale) membrane modeling techniques (finite element modeling, numerical methods, coarse graining methodologies; and (3) techno-economic analysis of advanced membrane-based separations, including applications for water purification, alkanes/alkenes, carbon capture, fuel cells, and more.

High-Throughput Systems for Membrane Materials Assessment
Chair: Georges Belfort (belfog@rpi.edu) & Chip Kilduff (kilduff@rpi.edu)
Development of new membrane materials is a keystone of membrane process development, to realize improvements in flux, selectivity, functionality, and anti-fouling properties. Modification of membrane surface chemistry and structure has been employed as an effective way to optimize membrane surface chemistry for specific feeds. Development of such new materials requires testing, which is laborious and expensive. High-throughput techniques offer efficient strategies to test new materials and chemistries. This session will focus on the application of high throughput techniques for testing new materials, including new polymers and polymer blends, and new surface chemistries developed via such strategies as bulk modification, interfacial polymerization, and graft polymerization. We will organize submissions around themes that emphasize high throughput strategies for assaying membrane performance for specific feeds, optimizing membrane processes, and probing separation and fouling mechanisms.

Advances in Membrane and Materials Characterization
Chair: Weiyi Li (liwy3@sustc.edu.cn), Maria-Chiara Ferrari (M.Ferrari@ed.ac.uk), Chuyang Tang (chuyang.tang@unsw.edu.au)
This session will focus on novel characterization methods and their applications to the better understanding of membrane materials and processes. The session will highlight methods that resolve the fine chemical and structural features of materials as well as tools with improved spatial/temporal resolution. Novel techniques for detailed investigation of membrane processes will also be emphasized. We plan to organize the sub-sessions around different aspects of characterization, including: (1) membrane material and structural characterization; (2) novel methods or tools for characterizing the kinetics of material synthesis; and (3) process characterization (e.g. fluid dynamics, membrane fouling, integrity monitoring, etc.). We hope that the contributions to these sessions will allow the participants to gain deeper insights of different membranes and membrane processes, which aids their further development and optimization.
NAMS 2019 Overview Of Technical Sessions

Membrane Materials, Continued

Innovations in Membrane Synthesis and Casting
Chairs: Rachel Dorin (rachel.dorin@teraporetech.com) & Ulrich Wiesner (ubw1@cornell.edu)
This session will be a forum for exploring novel materials and methods used in the field of membrane science and technology. Unique organic and inorganic material sets, new structures, and innovative formation pathways offer opportunities for realizing the next-generation of separation technology. Contributions to Innovations in Membrane Synthesis and Casting should contain elements that demonstrate ways to push and expand the boundaries of existing membrane platforms.

Inorganic Membrane Materials
Chairs: Jay Kniep (jay.kniep@mtrinc.com) & Jerry Lin (jerry.lin@asu.edu)
This session welcomes submission of papers on synthesis, characterization, property study, and process design of all inorganic membranes, in particular, membranes for molecular separation applications. These will include microporous and dense membranes for separation of gas and liquid mixtures.

Process Improvement

Fundamentals of Process Modeling and Technoeconomic Assessment
Chairs: Ivy Huang (ihuang@mtrinc.com) & Albert Kim (AlbertSK@hawaii.edu)
Scientific breakthroughs of fundamental mechanisms and novel materials are utilized through realistic, cost-effective processes for long-term, stable operations. This session focuses on, but not limited to, optimization of pre-existing processes with low-energy consumption rates and/or low capex merits, new hybrid membrane separations to combine multiple processes, and proof-of-concept approaches to developing novel industrial processes. We seek for modeling studies that can range from micro- to macro-scale analyses including quantum mechanics, molecular dynamics, computational fluid dynamics (CFD), particle hydrodynamics, and industrial cost analyses. Specific topics to be welcome include (1) holistic modeling approaches from material design to economic analysis, (2) fundamental scientific issues such as new statistical mechanics for membrane phenomena and non-equilibrium thermodynamics coupled with CFD, (3) seamless coupling of osmotically and thermally driven processes, and (4) industrial/plant-scale cost-analyses as originated from technological aspects of specific membrane processes. All other new theoretical and simulational approaches for academic advances are welcome.

New Concepts in Hybrid Processes and Process Integration
Chairs: Ed Sanders (ed.sanders@airliquide.com) & Jia Wei Chew (jchew@ntu.edu.sg)
This session will entertain papers that focus on combining two or more membrane processes or combining a membrane process with one or more non-membrane processes. Papers that discuss novel hybrid processes are particularly encouraged. Examples of processes of this type would include forward osmosis combined with distillation or extraction to regenerate the draw solution or pressure-retarded osmosis that uses membrane technology in combination with a device to convert the osmotic potential into mechanical or electrical energy.

Innovations in Module Modeling and Design
Chairs: David Ladner (ladner@clemson.edu) & Grigorios Panagakos (Grigorios.Panagakos@netl.doe.gov)
This session addresses recent developments in understanding the hydrodynamics and mass transport in membrane modules and systems. Both analytical and computational modeling – coupled with experimental verification – has yielded insight into fluid and solute flow. This insight has enabled the creation of new module designs and process configurations that allow greater water/solvent recoveries and lower energy costs. Examples include computational fluid dynamics (CFD) modeling of spacers and membrane morphologies (patterns) for reduced fouling in reverse osmosis, two-phase (gas and liquid) flow for scouring in membrane bioreactors, and minimizing pressure drop through design of modules tailored to gas separations.
Process Improvement, Continued

Advances in Real-Time Process Monitoring, Control, and Automation
Chairs: Yoram Cohen (yoram@ucla.edu) & Mandy Hering (Mandy.Hering@baylor.edu)
This session will focus on approaches for enabling and improving membrane-based water and wastewater treatment processes via the development and application of data-driven, statistical, or machine learning models for process optimization, intensification, and self-adaptive operation. The development of new methodologies, as well as novel applications of existing methods are both welcome. Work in the following areas are particularly of interest, including, but not limited to, membrane monitoring, predictive maintenance, model-based control, optimal operation, and overall process and plant management. Topics of interest also include, for example, multivariate data-driven methods for monitoring, integration of real-time data into control and feedback loops, automating systems and processes, and impact of the above on cost reduction and extension of membrane lifetime.

Fundamentals of Predicting and Preventing Membrane Fouling
Chairs: Manish Kumar (manish.kumar@psu.edu), David Mattia (d.mattia@bath.ac.uk), & Saifur Rahaman (saifur.rahaman@concordia.ca)
Fouling is inevitable for membrane-based processes and is considered to be one of the major challenges for further adoption of membranes in industry. This session will focus on the fundamentals of predicting and preventing membrane fouling. The topics of interests for this session include: (1) the origin, phenomena and mechanisms of membrane fouling and scaling; (2) advanced technology to monitor fouling and evaluate foulant composition; (3) advanced strategies and membrane module design to control membrane fouling and scaling; (4) new membranes materials, membrane structures and processes to minimize fouling/scaling performance of membrane; and (5) life cycle cost analysis of membrane fouling in real applications. This session will provide opportunities to exchange knowledge related to recent innovations and advances in predicting and preventing membrane fouling; and also, to discuss the energy efficiencies of different strategies for controlling membrane fouling.

Innovations in Microfiltration and Ultrafiltration
Chairs: Beth Goodrich (elizabeth.goodrich@emdmillipore.com) & Vlad Tarabara (tarabara@egr.msu.edu)
This session will focus on recent developments in micro- and ultrafiltration, with a strong focus on device, system, and processing innovations that could be leveraged across multiple application areas. Contributions on the following topics are welcome: (1) advances in MF and UF device design to address challenging separations and delicate products; (2) novel systems to enable continuous, sterile, or single-use MF, UF, and DF operations; (3) new methods for integrity testing; (4) design of MF and UF processes to control fouling; and (5) scalable and predictive systems and tools for high-throughput screening and process development of UF and MF applications. Case studies demonstrating improvements in capacity, productivity, cost of goods, or speed to manufacturing resulting from the use of these new MF and UF processing strategies are also encouraged.

Case Studies in Process Scale-Up
Chairs: JR Johnson (j.r.johnson@exxonmobil.com) & Bharat Bhut (bharat.bhut@merck.com)
In an effort to demonstrate the ‘real world’ value of membrane technologies, we are welcoming papers to discuss examples of successes – and failures – with respect to demonstration of membranes technologies at pilot and commercial scale. Preference will be given to novel application of membrane technologies and hybrid or integrated unit operations that includes membrane technologies. These case studies could include: proof-of-concept at pilot scale, field tests, and manufacturing scale-up/at scale demonstration. We anticipate a breadth of applications from various industries to be included in this session, such as water treatment, biopharmaceuticals, bioprocessing, biotechnology, chemical/refining technology, and energy production. The anticipated outcome of this session is to exhibit the challenges of technology scale-up and demonstrate the impact that membrane technologies can have in improving traditional or enabling future separation challenges.
**Membrane Distillation and Pervaporation: Innovations in Process Design and Scalability**

*Chairs: Lee Vane (Vane.Leland@epa.gov) & David Warsinger (dwarsing@purdue.edu)*

This session will focus on the module configurations, module design, energy sources, materials, and scalability for implementing evaporation-based separation technologies. These areas will be unified by their impact on energy efficiency, with an aim for competitiveness on cost and on efficiency with other thermal processes. Subsessions are intended on: (1) solar-thermal and light-absorbing nanomaterials for membrane distillation; (2) progress and promise of new configurations for enhancing performance, including vacuums, multistaging, and conductive materials; and (3) scaling-up: techno-economic analysis and competitive applications.

**Process Innovations in Electrofunctional and Electrocatalytic Membrane Processes**

*Chairs: Charles de Lannoy (delannoy@mcmaster.ca) & David Jassby (jassby@ucla.edu)*

The coupling of electrochemical and electrokinetic phenomena to membrane separation processes has been demonstrated to dramatically enhance membrane performance in areas such as anti-fouling, enhanced selectivity, enhanced flux, and selective degradation of contaminants. Our symposium will focus on recent innovations and developments in the areas of new membrane materials that enable electro-functionality and electrocatalytic properties, new electrical conductive membrane configurations and geometries, novel separation processes that take advantage of electrically driven phenomena, and electrically-based process intensification efforts revolving around membrane separations. The symposium will accept abstracts for oral and poster presentations on the fundamentals and applications of these membrane processes. The topics that would be covered in this session are, but are not limited to: electro-functional membrane materials; electrocatalytic reactions and processes on membranes; electrokinetic phenomena at the membrane/water interface; electrochemical reactions on the membrane surface; fundamental studies on electro-driven interfacial phenomena; mathematical and molecular modeling of electro-driven membrane processes; chemical and physical characterization of electrofunctional membranes; and sustainability considerations in the electro-membrane space.

**New Concepts in Osmotically Driven Membrane Processes**

*Chairs: Tony Straub (tonystraub90@gmail.com) & Aaron Wilson (aaron.wilson@inl.gov)*

This session will explore recent innovations in membrane systems that utilize an osmotic driving force. Osmotically driven systems can be used where conventional pressure-driven or thermal systems are have limitations or undesirable side effects. Presentations included in this session will offer new concepts through the implementation of novel materials, process innovations, improved system designs, and theoretical models. These developments can further expand the potential of osmotically driven membrane processes for applications such as desalination, high salinity brine treatment, food processing, chemical separations, and power generation.
NAMS 2019 OVERVIEW OF TECHNICAL SESSIONS

APPLICATIONS: ASSESSING PERFORMANCE, ROBUSTNESS, AND SCALABILITY

Seawater Desalination
Chairs: Sunny Jiang (sjiang@uci.edu) & Bill Phillip (wphillip@nd.edu)
This session will focus on the membrane application in seawater desalination. The areas of interest include membrane fouling and mitigation strategies, ion separation efficiency and selectivity, and membrane fouling and integrity monitoring. The session is not limited to reverse osmosis membrane desalination, presentations in novel membrane applications in seawater desalination, such as hybrid thermal or solar membrane distillation, forward osmosis, and pressure-retarded osmosis membrane operation for energy generation from seawater, are also welcome.

Brine Treatment for Minimal and Zero Liquid Discharge
Chairs: Radasav Vidic (vidic@pitt.edu) & Kerri Hickenbottom (klh15@email.arizona.edu)
This session will focus on the applications of membrane technologies for treatment of low, medium and high salinity brines to achieve zero liquid discharge. We would like to include lab-, pilot-, and full-scale studies with a variety of brines (i.e., brackish water, seawater, produced water, industrial effluents, RO concentrates) to showcase innovative solutions that are unique to membrane technologies. We are soliciting contributions that address performance and scalability of these systems as well as techno-economic assessment and comparison with other technologies.

Membrane Bioreactors
Chairs: Moshe Herzberg (herzberg@bgu.ac.il) & Adam Smith (smithadam@usc.edu)
This session will focus on performance enhancement and implementation of both aerobic and anaerobic membrane bioreactors. Interdisciplinary approaches that integrate novel membrane materials, evaluate new membrane configurations and reactor design, optimize membrane and reactor operating conditions, and elucidate the role of the microbial community in membrane fouling and process performance are strongly welcome. This includes membrane biofouling control strategies, integrating membrane design and process, methods to improve resource recovery (e.g., water, nutrients, and energy), and field studies of full-scale systems with an emphasis on scale-up of novel processes and design.

Contaminant Removal
Chairs: Andre Da Costa (adacosta@mtu.edu) & Prakhar Prakash (Prakhar.Prakash@chevron.com)
This session will focus on membrane separation for water purification. Water sources include municipal water, surface waters (such as lakes, rivers and reservoirs) and groundwater, including produced water. Contaminants may include inorganic impurities and particles, biological impurities (viruses/bacteria) and organic impurities such as natural organic matter (NOM), emerging organics such as PFAS or oil resulting from accidental spills or production operations. Contamination may occur due to agricultural land run off, industrial pollution or pipeline corrosion. We welcome papers addressing membrane performance (permeation properties, fouling and integrity) and process design/pilot studies for any of the water sources referred above.

Water Reuse
Chairs: Pei Xu (pxu@nmsu.edu) & Jack Gilron (jgilron@bgu.ac.il)
This session will focus on the opportunities to apply membrane technologies to the re-use of water in many different contexts. What unites all these contexts is that they involve recovery of water which has interacted with human-impacted environments. We plan to organize the sub-sessions around different water sources, including: (1) industrial wastewater (e.g. pharmaceutical, power, food, mining, animal husbandry); (2) municipal wastewater; and (3) runoff (e.g. stormwater, agricultural runoff).
Energy Applications: Assessing Performance, Robustness, and Scalability for Carbon Capture

Chairs: Dave Hopkinson (David.Hopkinson@netl.doe.gov) & Winston Ho (ho.192@osu.edu)

Membrane-based carbon dioxide capture technologies face several key challenges to progress from lab scale to pilot and large demonstration scale. Materials must have high performance while also being inexpensive, easily fabricated into a thin film composite, and exhibiting robust behavior in the presence of moisture and other contaminants. For post-combustion carbon capture, the membrane support, module, and system must be optimized to accommodate a low CO₂ partial pressure driving force and a very large volume of gas to be processed. On pre-combustion carbon capture, the membrane support, module, and system should be amendable to take advantage of high CO₂ partial pressure and able to sustain the large pressure differential and maintain good stability to high-level H₂S. Topics of interest for this session include: performance of membrane materials for both post- and pre-combustion carbon capture; testing with simulated or real flue/synthesis gas, particularly in the presence of water and contaminants; module and system design for carbon capture; long-term testing; scale-up demonstrations of membranes for carbon capture; and techno-economic analysis along with CO₂ capture cost optimization.

Fuel Cells and Batteries

Chairs: Michael Guiver (michael.guiver@outlook.com), Mike Hickner (hickner@matse.psu.edu), & Peter Pintauro (pn.pintauro@Vanderbilt.edu)

This session will address critical issues, novel approaches, new insights and significant performance enhancements as related to polymeric cation-exchange and anion-exchange membranes for fuel cells, electrolyzers, and redox flow batteries. Contributions on recent research results dealing with fundamental and applied work in any area of ion-exchange membrane development, characterization, and use are welcome. Examples of topics include: (1) New membrane materials, morphologies and cell performance for high temperature proton-exchange membrane (PEM) fuel cells, especially under reduced relative humidity conditions; (2) high conductivity, chemically robust anion-exchange membranes for fuel cells and electrolyzers; (3) ion selective membranes for redox flow batteries; and (4) structure/function membrane modeling studies.

Salinity Gradient Energy

Chairs: Emily Tow (emilytow@alum.mit.edu), Chris Gorski (gorski@engr.psu.edu), & Kitty Nijmeijer (d.c.nijmeijer@tue.nl)

Salinity gradient energy technologies have the potential to provide significant renewable energy, but performance and system limitations have prevented widespread use. Whether energy is generated by pressure-retarded osmosis, reverse electrodialysis, thermo-osmotic engines, or other novel processes, economic viability will depend highly on fouling control, reducing mass transfer resistances, and optimizing operating conditions and systems design. This session will be organized around the following issues: (1) monitoring and control of fouling; (2) transport phenomena; (3) optimizing operating conditions and systems design; and (4) performance & economic analysis.

Biofuels Processing

Chairs: Handan Tezel (Handan.Tezel@uottawa.ca) & David Sievers (David.Sievers@nrel.gov)

This session will focus on opportunities for, and experiences with, applying membrane technologies to biomass-based fuel and chemical processing. This is a relatively new field for membrane technology use and many opportunities exist, including but not limited to liquid product recovery and solid-liquid separation applications. We anticipate that the contributions to this session will allow the participants to appreciate the characteristic challenges of biofuel processing unit operations and how membrane technology can improve the quality, robustness, and/or scalability in this area.
Protein Purification

Chairs: Merlin Bruening (mbruenin@nd.edu) & Jessica Molek (jessica.r.molek@gsk.com)

This session will highlight the latest advances of membrane technologies for purification of peptides and proteins, including monoclonal antibodies and tagged proteins. Topics to be covered include, but are not limited to: microfiltration, ultrafiltration, nanofiltration, and membrane chromatography and adsorption. Case studies that demonstrate assessment of robustness and scalability are of interest and encouraged.

Purification of Non-Protein Biologics

Chairs: James McGrath (jm McGrath@rochester.edu) & Onur Kas (onur.kas@endemillipore.com)

While monoclonal antibodies currently dominate the therapeutic biologics space, non-protein biologics such as viral vectors and oncolytic viruses are moving through clinical trials and emerging as approved drugs. Similarly, there is a growing interest in non-protein biologics such as extracellular vesicles and cell-free DNA as diagnostic targets. Although interest in non-protein biologics is growing, strategies for their purification are still under development. This session will highlight and compare current methods for purifying non-protein biologics and explore the impact of their characteristics, such as size and functionality, on the performance of purification strategies.

Cell Harvesting/Clarification/Processing

Chairs: Ralf Kuriyel (Rkuriyel@repligen.com) & Sen Xu (sen.xu@merck.com)

This session will focus on the opportunities to apply membrane technologies in bioprocessing. Contributions related to topics such as membrane-based cell culture production, clarification, cell harvesting, and perfusion are welcomed. We hope that the contributions to the session will allow participants to appreciate the use of existing and new membrane technologies being applied/explored in cellular bioprocessing.

Conference Co-Chairs:

▷ David Latulippe, McMaster University
▷ Meagan Mauter, Carnegie Mellon University
▷ Andrew Zydney, Penn State University