THE UNIVERSITY OF QUEENSLAND
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Membrane Society of Australasia

4th MSA Workshop & Networking

Title: Ceramic based membranes for gas separation applications

Date/Time: 7th August 2015, 10:00 to 18:00.

Venue: Level 1 conference room, Australian Institute for Bioengineering and Nanotechnology (Building 75; Corner College and Cooper Roads), The University of Queensland (UQ), Brisbane

Contact: Dr David Wang (mob: + 61 423 876 040; d.wang1@uq.edu.au) and Dr Guozhao Ji (mob: + 61 430 646 119; g.ji@uq.edu.au)

Workshop Schedule

Time	Speaker	Affiliation	Title
1000	**Opening welcome message**		
1030	Prof Joe da Costa	UQ	Structural functional tailoring of silica membranes
1100	Dr Julius Motuzas	UQ	Use of zeolite membranes in gas separation
1130	Dr Simon Smart	UQ	Ceramic membranes for O_2 production
1200 1230	**Lunch**		
1300	Dr Marlies Hankel	AIBN/UQ	Theoretical studies of 2D carbon membranes for gas separation
1330	A/Prof Guotong Qin	BAU	Carbon membranes for gas separation: carbonization and elimination of defects
1400	Dr Michael Dolan	CSIRO	A low-temperature membrane reformer for solar hydrogen
1430	Prof Shaomin Liu	CU	Morphological evolution of inorganic hollow fibre membranes prepared by phase inversion and sintering method
1500	**Afternoon break**		
1530	Mr Stefan Smith	CSIRO	Inorganics in polymer membranes
1600	Ms Melanie Kitchin	CSIRO	Ending aging in super-glassy polymer membranes using organic nanoparticles
1630	Dr Lei Ge	UQ	Manipulating MOF/polymer interface in mixed matrix membranes
1700	Prof Firas Rasoul	KISR	Overview of research at KISR and requirements for low energy separation technology
1730	**Closing and discussion**		
1800	**Go to dinner networking (location to be advised)**		

*Both lunch and afternoon tea are provided
^Dinner and drinks will be paid from personal expenses

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Workshop Speakers: Abstract and Biography Information

Name(s): Prof. Joe da Costa

Affiliation(s): The University of Queensland

Presentation title: Structural functional tailoring of silica membranes

Abstract:

The structural functionalities of silica derived membranes can be tailored with metal oxides. As a result, high quality membranes are prepared with tailor made pore sizes in the region of 3 Å, thus allowing the passage of the smaller gas whilst hindering the diffusion of larger gases. These membranes deliver molecular diffusion controlled transport leading to temperature dependence known as activated transport. This presentation will discuss the current status in metal oxide functionalization, leading to improved hydro-stability of silica membranes, or improved pore size control, long term stability testing, and the redox effect pore size tailoring via binary metal oxide and silicate formation. The performance of the membranes will be discussed in terms of single and binary gas mixtures up to 500ºC, in addition to future challenges.

Short bio:

Joe da Costa is the Director of the FIM^{2}Lab – Functional Interfacial Materials and Membranes Laboratory, and a Professor in the School of Chemical Engineering at the University of Queensland, Brisbane Australia. Currently he holds a Future Fellowship from the Australian Research Council, in addition to an editorial board membership in Nature's new open source journal Scientific Reports. Joe has over 30 years working experience in industrial, consultancy and academic roles in Brazil, England and Australia. Currently, he leads several research projects in the area of membranes for gas and liquid separation. Joe has over 200 international publications including 8 book chapters on membranes and membrane reactors, a H-index of 31 (web of science) and several patents. He is a Chartered Professional Engineer in the Colleges of Mechanical Engineering and Chemical Engineering of the Institution of Engineers Australia

Name(s): *Dr Julius Motuzas*

Affiliation(s): The University of Queensland, FIM²Lab – Functional Interfacial Materials and Membranes Laboratory, School of Chemical Engineering, Brisbane Qld 4072, Australia.

Presentation title: Use of Zeolite membranes in gas separation

Abstract:

Zeolites are microporous, crystalline materials used as powder, thin films or membranes. Zeolites as particles are already widely implemented in industrial processes including catalysis and sorption, whilst the zeolite membranes are still emerging technology. The considered application niches of the zeolite membranes vary depending on the zeolite pore structure and size. They may be used in liquid and gas separation, sensors as well as membrane reactors if the pores size is appropriately selected.

There are two types of zeolite membranes in means of morphology. The first one is monocrystalline membranes; however their preparation is very difficult and for this reason they are rarely considered for use. The commonly used zeolite membranes are polycrystalline. These membranes are formed by intergrowth of multiple crystals during the membrane formation.

Within this talk, possible ways of the polycrystalline zeolite membrane preparation by direct growth and their application in gas separation will be overviewed. In addition, several examples on the post-synthesis modification methods to tune zeolite pore size up to desired for the process will be presented.

Finally, challenges and opportunities in the zeolite membrane development and implementation will be also discussed.

Short bio:

Julius Motuzas is a scientist working on inorganic membrane preparation and application for energy production and gas separation. He earned his Bachelor (2001) and Master (2003) of Chemical Engineering at Kaunas University of Technology (Lithuania) and his PhD in Materials Science from the Second University of Montpellier (France) in 2006. In his thesis work he pioneered the MFI zeolite nanoseed and membrane synthesis using microwave hydrothermal method. Afterwards, he continued research on microporous membrane synthesis and application as Research Fellow at the University of Twente (the Netherlands), the European Institute of Membranes (France) up to 2011.

In 2012, Dr Motuzas as a Research Fellow has joined the Films and Inorganic Membranes Laboratory. His current research is focussed on Perovskite and microporous membranes, including zeolites, for gas separation and catalysis.

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Name(s): *Dr Simon Smart*

Affiliation(s): The University of Queensland

Presentation title: Ceramic Membranes for O_2 production

Abstract:

Coal is the most abundant fossil fuel in the world and is likely to outlast gas and oil for centuries. However, with global issues like climate change at the forefront of public attention there is a trend towards the development of a carbon constrained economy. As a result, research has intensified in the last decade on modes of operating coal fired power plants with carbon capture and storage (CCS). Oxyfiring is one of the more promising options as it produces a nearly pure CO_2 stream, reducing carbon capture costs. However, this comes at the cost of having to separate oxygen from air at the front end. Ceramic membranes offer the opportunity to reduce oxygen production costs and energy requirements by improved heat integration. Here we present a decade of development on mixed ionic electronic conducting (MIEC) membranes for oxygen production. Through advanced manufacturing techniques and careful material selection we can improve membrane flux and stability and reduce operating temperatures which goes some way towards improving their commercial applicability.

Short bio:

Simon Smart is a Senior Lecturer in the School of Chemical Engineering at The University of Queensland, where he leads research into membrane and membrane reactor technologies for clean energy and water applications. His work involves the. As the deputy-director of Functional and Interfacial Materials and Membranes Laboratory (FIM^{2}Lab), the major focus of his research has been on the design and development of inorganic and hybrid nanocomposite materials for membranes and membrane reactors, developing enabling separation technologies to increase the efficiency and decrease the cost of hydrogen and oxygen production, CO_2 capture and treatment of waste waters from the mining and coal seam gas industries. He has a keen interest in the industrial applicability of new separation technologies including scale-up, design and cost estimation. He has written 54 publications including 8 book chapters and 46 journal papers.

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Name(s): ***Dr Marlies Hankel***

Affiliation(s): ***AIBN, The University of Queensland***

Presentation title: Theoretical studies of 2D carbon membranes for gas separation

Abstract:

Membrane separation of gases is desirable due to its low cost and various membranes have been developed for hydrogen separation such as metallic, silica, zeolite, carbon-based and polymer membranes. However, as the permeance of a membrane is inversely proportional to its thickness a one atom thick membrane presents the ultimate membrane. The field of gas separation via one atom thin, 2D, membranes is still in its infancy. We will report the recent research into 2D carbon based membranes such as porous graphene, graphdiyne and carbon nitrides and their application to separate hydrogen from methane and other gases as well as hydrogen isotope H_2/D_2 separation.

Short bio:

Marlies Hankel is computational scientist with research interests in 2D carbon membranes for gas separation and lithium ion battery applications. After her master studies in Mathematics in her home country Germany she moved to the UK to start a PhD in Theoretical and Computational Chemistry at the University of Bristol in the group of Prof. Gabriel Balint-Kurti. After a two year postodc at the University of Manchester in the group of Prof. Jonathan Connor she moved to UQ in 2004 to work in the group of Prof. Sean Smith. Here she slowly changed her research field from tri atom reactive scattering reactions in the gas phase to applications of 2D carbon membranes in gas separation and lithium ion batteries.

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Name(s): *Dr Guotong Qin*

Affiliation(s): Beihang University, Beijing, China / School of Chemical Engineering, the University of Queensland

Presentation title: Carbon membranes for gas separation: carbonization and elimination of defects

Abstract:

Carbon molecular sieve membrane exhibits promising potentiality in gas separation. H_2/N_2 and O_2/N_2 can be separated effectively. Carbon membrane originates from carbonization of thermal setting polymer. Structure rearrangement, aromatization, partial fusion and shrinkage of the polymer occur during carbonization. Carbon membranes for microfiltration, ultrafiltration and gas separation can be obtained from the same precursor through the control of the preparing process. Besides the modification of pore size, the partial fusion of polymer during carbonization is benefit to release the shrinking stress and to eliminate the defects of membrane. The method for preparing carbon membranes and the characteristics of carbon membrane has been introduced.

Short bio:

Dr. Qin is working as a visiting scholar in the school of chemical engineering in the University of Queensland. He is an associate professor in the school of chemistry and environment in Beihang University, China. He worked as postdoctoral fellow in Tsinghua University in China for two years (1999-2001) and worked as research associate in the Hong Kong University of Science and Technology (Jan 2011-Jul 2011). He got his PhD degree and master degree in 1999 and 1996 in Dalian University of Technology, China. His research interest focus on sol-gel process, porous materials and application of porous materials in adsorption, membrane separation, catalysis and thermal insulation. His work has got continuously financial support from the National Natural Science Foundation of China. He has published about 30 peer viewed journal papers and 3 patents.

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Name(s): Dr Michael Dolan

Affiliation(s): CSIRO

Presentation title: A low-temperature membrane reformer for solar hydrogen

Abstract:

Concentrated solar thermal power (CSP) is caught in a Catch 22 – the technology costs remain high due to its limited deployment, but economic investment is unfavourable because CSP is used almost exclusively to create a low-value product (electricity). This situation could be addressed by using CSP to create higher value chemical and metallurgical products, but its inherent intermittency is at odds with the requirement for continuous operation in many industrial processes. Thermal energy storage (TES), whereby solar heat is collected during the day and released later, is one solution to this problem, but the available temperatures from TES are limited to ~550°C. Process conditions must therefore be modified if necessary to ensure compatibility with TES.

Solar-assisted natural gas reforming, whereby the large reaction endotherm and steam generation is provided by solar heat, has been demonstrated at near-commercial scale, but the temperature demand (~850°C) makes it unsuitable for TES integration. By using a membrane reformer, however, in which the generated H_2 is extracted in situ through a membrane, allows high conversions to be achieved at temperatures as low as 550°C.

Recent efforts in CSIRO to develop a TES-integrated membrane reformer for solar hydrogen will be discussed. This system incorporates 4 tubular membrane reformers in parallel, each containing Pd-ceramic membranes and commercial Ni-based reforming catalyst. The system is integrated with TES via a heat exchange fluid (CO_2 or air) which is circulated through two heat exchangers (reformer and pre-heater). CH_4 conversion, H_2 yield and H_2 purity will be discussed in the context of several input and operating parameters, along with the findings of a techno-economic assessment.

Short bio:

Michael holds a B. App Sci (Hons – 1st) in Chemistry, and a PhD in metallurgy, both from La Trobe University. After graduating he undertook a post doctoral fellowship in Glass Science at the New York State College of Ceramics. Michael joined CSIRO in 2001 as a post-doctoral fellow, and is now a senior research scientist and leader of the Gasification Processes team. Michael's research concerns the development of hydrogen-selective alloy membranes, and their application in industrial processes such as pre-combustion CO_2 capture and natural gas reforming. His research ranges from fundamental (alloy development, studies of metal-hydrogen interactions in crystalline and amorphous alloys, hydride phase equilibria) to applied (membrane reactor development, scale-up of manufacturing, solar integration).
Michael has published 45 journal articles and one holds provisional patent.

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Name(s): ***Prof. Shaomin Liu***

Affiliation(s): ***Department of Chemical Engineering***

Presentation title: Morphological Evolution of Inorganic Hollow Fibre Membranes Prepared by Phase Inversion and Sintering Method

Abstract:

Just like polymeric membrane, inorganic membrane in hollow fibre geometry has been widely investigated and is becoming one important part of inorganic membrane development. The early research related to the phase inversion and sintering method to prepare inorganic hollow fibre membranes can be dated back to the late 1990s. In those early years, only a few groups were working in this area; now this technology has been widely accepted and applied in 20 laboratories worldwide. Despite the fact that this method is very versatile and can be facilely tuned to prepare many membranes from different materials, there are still some underlying principles that need to be understood or followed. In this presentation, the speaker will talk about the morphological evolution of the inorganic hollow fibre membranes with the variation of preparing conditions from three typical materials alumina, perovskite and stainless steel. Membrane morphology is one of the most important factors that determine the membrane performance.

Short bio:

Shaomin Liu is an ARC Future Fellow and Professor in the Department of Chemical Engineering at Curtin University. Liu received his Ph.D. degree from the National University of Singapore in 2002, and then worked as a postdoctoral research fellow in Chemical Engineering at the California Institute of Technology from 2002 to 2005. From 2006 to 2008, he was working in the University of Queensland. From the end of 2008, he has been working in Curtin University, Australia. He is the recipient of an ARC Future Fellowship (2012-2016) and an ARC Australian Research Fellowship (2008-2012). His research interests include inorganic membranes for gas separation, membrane reactors for gas reaction, nanoporous materials, solid oxide fuel cells, bioceramics, nanoparticles for antimicrobial property and water treatment. He has published over 200 journal papers.

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Name(s): *Mr Stefan J. D. Smith*

Affiliation(s): **Monash University, Department of Chemical Engineering, Clayton, VIC 3800, Australia;** *CSIRO, Manufacturing Flagship*, **Private Bag 33, Clayton South MDC, VIC 3169, Australia.**

Presentation title: ***Inorganics in Polymer Membranes***

Abstract:

Metal Organic Frameworks (MOFs) are an emerging class of organic-inorganic nanohybrid materials useful for applications including molecular storage, catalysis, energy-generation, and more importantly, separations. MOFs consist of a metal node connected by organic linkers in a periodic manner, giving them one of the highest known surface areas. MOFs can also be employed as adsorbents for carbon capture, and heavy metal sequestration. However, to use these contemporary nanomaterials for such applications, it is estimated that 2,100 tonnes of MOFs are required to implement full-scale carbon dioxide capture and sequestration on an average coal-fired power station.

Impregnation of MOFs in polymeric membranes, forming mixed matrix membranes, is a significantly more feasible route to low energy carbon capture and sequestration. In this presentation, I will discuss about how MOFs can improve the gas permeability, selectivity, and physical aging in super glassy polymer membranes. These improvements only require 5 wt. % MOF loading. I will also present on recent work in using such membranes for hydrogen purification, organic solvent nanofiltration, and also hydrocarbon separations.

Short bio:

Stefan commenced PhD study in 2013 under the collaborative supervision of Associate Professor Bradley Ladewig, of Monash University, and Dr Matthew Hill and Dr Cher Hon Lau of CSIRO.

Stefan's work centers on the development of super glassy polymer nanocomposite membranes, using MOFs and other porous frameworks. These membranes have been used for carbon capture, hydrogen purification, and organic solvent nano-filtration and are a core research focus of CSIRO's MOF Platform Technology. His research aims to tune the polymer-particle interaction to optimise separation performance and mechanical properties, and its affect on aging; key factors to the application of nanocomposite membranes to industrial processes. Recently, Stefan's initial work on high performance Mixed Matrix Membranes containing Titanium exchanged Metal-Organic Frameworks was published by Scientific Reports.

Prior to PhD study, Stefan was the Carbon Capture Chemist for the Aberthaw Carbon Capture Pilot Plant, a joint project between RWE npower (UK) and Cansolv Technologies (Canada). The 3 MWe 'capture and release' plant utilised proprietary amine solvents to separate carbon dioxide and sulfur oxides from the coal-fired Station's (1600 MW) flue gas.

Name(s): ***Ms Melanie Kitchin[1], Kristina Konstas[1], Sam Lau[1], Colin Wood[1], Xavier Mulet[1], Anita Hill[1], Richard Noble[2] and Matthew Hill[1]***

Affiliation(s): ***[1] CSIRO Manufacturing Flagship, Clayton, 3168, VIC, Australia***
[2] Department of Chemical and Biological Engineering, University of Colorado, Boulder, CO, 80309 USA
[3] Centre for Advanced Nanomaterials and the School of Chemistry & Physics, The University of Adelaide, Adelaide, 5005, SA, Australia

Presentation title: ***Ending Aging in Super-Glassy Polymer Membranes using Organic Nanoparticles***

Abstract:

As a result of their initial permeability and selectivity properties, super glassy polymers present as attractive materials for incorporation in low-energy molecular separation technologies. Unfortunately, super glassy polymers naturally undergo physical aging, as polymer chains relax towards an unachievable thermodynamic equilibrium. As a result, free volume content is reduced and chain mobility is restricted as polymer chain packing density increases. A corollary of this aging process is a reduction in membrane permeability. Our work involves the exploration into, and the tailoring of, molecular interactions between several classes of microporous organic additives with the super glassy PTMSP- and PIM-1 polymers in order to overcome physical aging.

Here, we present our work on micro-porous organic polymers based on hypercrosslinked organic polymer networks, which exhibit a novel anti-aging mechanism based around membrane swelling.

We shall also present our work on mixed-matrix membranes incorporating porous aromatic frameworks (PAFs) as the microporous additives. As a result of the irreversible covalent nature of their organic framework, PAFs have high surface areas and superior stability when compared to other micro-porous systems, as well as large pore volumes that allow high gas storage capacity. The effect is achieved by an intimate mixing of polymer chains within the porous organic additive, with evidence of the side chains being notably tethered within these pores of the organic additive.

The nature of the intercalation of the polymers within each organic additive has been probed by gas transportation studies and complementary techniques of positron annihilation lifetime spectroscopy (PALS) and 13C solid state NMR.

Short bio:

Melanie commenced her PhD candidature in 2013 under the co-supervision of Drs Matthew Hill and Kristina Konstas of the CSIRO, and Assoc. Professors Christian Doonan and Chris Sumby of the University of Adelaide.

Melanie’s work focuses on tailoring polymer-additive interactions in order to optimise initial molecular separation properties of, and control membrane aging in, super-glassy polymers. In doing so, she works with several classes of organic and inorganic nanocomposite membranes. Her work also involves the development of novel asymmetric membranes for use in molecular separation technologies.

Melanie’s work on the effect of polymer-additive interactions on membrane aging in nanocomposite membranes was recently accepted into the Journal of Materials Chemistry A.

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Name(s): *Dr Lei Ge*

Affiliation(s): *University of Queensland*

Presentation title: Manipulating MOF/polymer interface in mixed matrix membranes

Abstract:

Metal organic frameworks (MOFs), with large surface area and selective gas adsorption capability, can be the promising additives in mixed matrix membranes (MMMs) for potential gas separation. However, interfacial defects can be observed between MOFs and polymer matrix which can be the underlying reason for the deterioration of gas selectivity and integrity of membrane structure. To tackle this issue, various approaches have been adopted to optimize MOFs/polymer interfacial interaction in this study. The first case study was employing facial ultra-sonication treatment to activate and reduce the particle size of MOFs filler. The second case study was applying tailored interfacial interaction in selected MOFs/polymer pairs through in-situ polymerization process.

The proposed membrane synthesis routes result in improving the adhesion between MOF particles and polymer phase as well as enhancing both gas permeability and selectivity of the derived mixed matrix membranes. The analysis of permeation and gas sorption results also indicates that MOFs improve both diffusivity and solubility of gas molecules thus enhancing the permeability and selectivity of the membrane. The membrane fabrication strategy we have shown here can provide experience for the MOF/polymer pair selection, MOFs activation and the interface manipulation in the fabrication of high performance MMMs by taking the advantage of organic linker on the surface of MOFs.

Short bio:

Dr Lei Ge is an early career researcher in the University of Queensland. Lei completed his PhD degrees in Chemical Engineering at the University of Queensland in 2013. Lei's PhD thesis investigated the use of carbon materials for efficient gas separation via membrane separation or adsorption. Dr.Ge has published 35 scientific papers in high quality international journals and a book chapter. His research interests include gas separation membrane, porous materials, adsorption, catalysis and fuel cells.

Name(s): *Prof. Firas Rasoul*

Affiliation(s): Petroleum Research Centre (PRC), Kuwait Institute for Scientific Research (KISR), PO Box 24885 Safat, 13109 Kuwait

Presentation title: Overview of research at KISR and requirements for low energy separation technology

Abstract:

Petroleum is the main source of energy and critical to the Kuwaiti economy and quality of life, as it makes nearly 85% of the country's gross domestic product (GDP). The petroleum industry in Kuwait addresses many important future challenges such as aging oil fields, deteriorating crude quality, increasing global demand for oil, continuing concern for the environment, governmental regulations and policies, higher consumer expectations for fuels and fuel delivery systems, and global competition. Therefore, innovative research and development will be needed to meet these challenges and profitability of the oil sector.
Petroleum Research Centre (PRC) is one of the leading research centres of the Kuwait Institute for Scientific Research. PRC Mission is to develop innovative solutions and provide advanced level of technical support to Kuwait and regional oil and petrochemical industries, through establishing new opportunities and interfacing with industrial collaborators. The focus of the centre's research programs are on improving proven reserves, enhancing oil recovery, meeting international requirements in terms of petroleum product quality, diversifying the utilization of hydrocarbon resources, maximizing the life time of assets, reducing production cost and developing new materials and processes.
In this presentation, we will present a general overview of the research programs and facilities at KISR with special emphasis on the need for new technologies for maximizing the utilization of refinery gases and to achieve low sulphur content fuel through the use of low energy separation processes, including membrane technology. We will also present some of our research requirement for the development of suitable surface modified membranes for RO and FO water desalination.

Short bio:

Firas Rasoul has gained wide experience in polymer science and technology through his association with various Industrial Research and Academic Organisations in the UK, Australia and the Middle East. He completed his PhD in Polymer Chemistry from Liverpool University, U.K. He worked with Smith & Nephew Research Group.
Currently he is a Senior Scientist at the Petroleum Research Centre, Kuwait Institute for Scientific Research, and also he is holding an adjunct position at the School of Chemical Engineering and School of Dentistry-University of Queensland.
Moved to Australia in 1991 and since then he worked in different positions: Polymer and Radiation Group, University of Queensland (1991-94), CRC for Polymers and RMIT (1994-96). From 1996-2000, he was the Chief Polymer Scientist with Chiron Technologies P/L Melbourne. Dr Rasoul co-founded Polymerat Pty Ltd in 2000 (a spin-off biotechnology company) which was then acquired by Anteo Diagnostics P/L in 2004. He then joined "The Australian Institute for Bioengineering and Nanotechnology (AIBN) and The Centre for Advanced Imaging (CAI) / UQ from 2004-2013.
He has published more than 120 Refereed journal publications, over 95 International conference presentations including (24) invited keynote talks in International conferences. 5 International Patents and PCTs and over 60 Commercial-in-confidence technical reports submitted to Industrial or Government agencies and numerous industrial forum and presentations.
He supervised research projects of many PhD students and postdocs and he was active in generating research funds from different funding groups, such as KFAS, Queensland Smart state, linkage grants and AusIndustry.