Incorporation of Nanomaterials Into PVDF Porous Membranes For Improved Water Treatment

Antoine VENAULT

Chung Yuan Christian University

The performance of porous poly (vinylidene fluoride) (PVDF) membranes, used in water treatment, can be significantly enhanced by nanomaterials. In this context, we discuss the use of MIL-53(Fe) and δ-MnO2, for the removal of antibiotics.
MIL-53(Fe) was blended with PVDF and membranes formed by the liquid-induced phase separation (LIPS) process, while δ-MnO2 was spray-coated on LIPS membranes. Both systems were utilized for the removal of tetracycline (TC) from water. The incorporation of MIL-53(Fe) into the casting solution strongly impacted the formation of macrovoids (cross-section), but spraying only affected the membrane surface. The optimized membrane containing MIL-53(Fe) achieved a 87% rejection rate against TC. Subsequently, the nanoparticles facilitated the degradation of 93% of the unrejected TC. On the other hand, the optimized membrane containing δ-MnO2 led to a rejection rate of 96% and the remaining TC was entirely degraded. Thus, these approaches both demonstrated highly competitive effectiveness and contribute to address the challenges posed by pharmaceutical products in wastewater.

Emerging Challenges for Virus Filtration: Validation of Virus Clearance and Virus Purification

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Virus filtration is a frequently used membrane process in the manufacture of biopharmaceutical products. In the manufacture of traditional protein-based therapeutics such as monoclonal antibodies (mAbs), virus filtration is used to validate virus clearance. The product of interest passes through the membrane which is run in normal flow mode. Virus particles are rejected by the membrane. Given that the smallest potential virus particles are around 22 nm and larger mAbs can have a hydrodynamic radius of more than 10 nm, this is a very challenging separation. At least 10,000 fold virus reduction and 95% protein recovery is required.

Today there are many emerging biopharmaceutical products based on virus particle and cells (cell therapies). Validation of virus clearance for these particle-based therapeutics introduces new challenges as fraction of different sized particle is now required. In this presentation recent experimental results from the Center for Membrane Applications Science and Technology and the Center for Membranes for Virus Clearance will be presented.

Preparation of organic–inorganic hybrid gas barrier membranes

Koji KURAOKA

Kobe University

The gas barrier properties of polymer membranes (films) are an important factor in their use as packaging materials. Gas barrier membranes, which have high barrier properties against oxygen and water vapor, are also important components in flexible electronics applications such as organic electroluminescence (EL) and solar cell panels. Organic-inorganic hybrid gas barrier membranes are promising candidates for such applications. Incorporation of inorganic segments at the molecular level in organic polymers has resulted in novel properties such as improved gas barrier property, mechanical strength and thermal stability. Furthermore, the incorporation of organic segments improves the brittleness of inorganic materials.
In this presentation, our recent research activities on organic-inorganic hybrid gas barrier membranes will be presented briefly.

Crosslinked intrinsic microporous polymers for efficient gas enrichment

Prof. Xiaohua MA

Tiangong University

Intrinsic microporous polymers have great opportunity in gas separation due to their simultaneously high permeability and selectivity. However, there are some intrinsic challenges such as plasticization and swelling. Crosslinking is considered as one of the most efficient ways to improve its separation performance and stability as well. Because of the crosslinking can significantly enhance the micropore and ultra-micropore of the PIM membranes. As a result, we developed a series of method for further enhancing the gas separation properties of PIMs, and as a result, define the 2024 trade-off lines for polymeric membranes.

Precise Construction of Anti-Fouling Polyamide Reverse Osmosis Membranes

Shuang HAO

Tiangong University

The development of high flux and highly fouling-resistant reverse osmosis (RO) membranes is crucial for addressing water crisis. However, it is still challenged to enhance the antifouling performance of the membrane against organic foulants, particularly charged small organic foulants. We herein reported the fabrication of antifouling thin-film composite (TFC) polyamide (PA) RO membranes having inner and outer zwitterion-like layers by a scalable layer-by-layer interfacial polymerization process to precisely control the hydrophilic and charge properties of the RO membrane. The modified RO membranes have a high water permeance of 3.92 L m-2 h-1 bar-1, while maintaining a NaCl rejection rate of 99.18 %. In addition, the obtained membranes exhibit excellent antifouling properties, surpassing most of the reported membranes. Our work provides insights to engineer the polyamide RO membrane surface with superior separation performance and efficient anti-fouling properties.

Ultrathin-film composite membranes prepared by molecular layer-by-layer deposition reaction.

Liping ZHU

Zhejiang University

Organic solvent nanofiltration (OSN) has shown great potential in the separation process of petrochemical and pharmaceutical industries, but it is extremely challenging to prepare OSN membranes with high permeance, high separation accuracy, and robust solvent resistance. The physicochemical structures of the membrane need to be rationally designed to achieve this goal, such as customized crosslinked networks, thickness, and pore size. Herein, we develop a method of molecular layer-by-layer deposition reaction to engineer contorted monomers for preparing tailor-made ultrathin films. The growth mechanism of nanofilms on porous and nonporous substrates is investigated. By elaborately designing monomer structures and controlling deposition cycle numbers, the nanofilms were endowed with enhanced microporosity, sub-nanometer micropores, and a tunable thickness under 50 nm. Resultantly, the composite membranes integrating ultrathin nanofilms exhibit adjustable solvent permeance and rejection curves. The efficient purification and concentration of the drug molecules and their intermediate are well achieved. Therefore, this facilitates the application of ultrathin nanofilms for precise molecular separation in OSN.

Functionalising membrane distillation process by stacking new layers on top of hydrophobic membrane

Jianhua ZHANG

Victoria University

Membrane distillation could deal with high salinity water, achieve theoretical 100% rejection to volatiles and is not prone to fouling as pressure driven process. However, membrane wetting, low or non-rejection to volatiles, no selectivity toward components and high thermal energy consumption confine its application. Hence, it is necessary to modify the membrane for the purpose to widen the application of membrane distillation, where it is difficult or not possible to utilise other membrane technology. Stacking extra layer(s) on top of hydrophobic layer of the membrane distillation membrane is one of the solutions to enhance the wetting resistance and membrane selectivity. However, delamination and low flux are typical issues for multilayer membrane. In this presentation, achievements of stacking layer(s) on membranes were introduced based on wetting resistance, selectivity improvement and durability.

Singapore START Centre: Taking Inventions to Products and Processes

Adil DHALLA

Singapore Membrane Consortium

There is a large gap between good inventions and market ready products and processes. The biggest challenge for commercialization of novel ideas, even if the Intellectual Property is duly protected, is the gap between laboratory processes, results and testing, and the full-scale final product. Key risks include scale-up of component materials and equipment, systems level thinking, testing at pilot scale in an actual application setting, and final implementation. The Separation Technologies Applied Research and Translation (START) Centre, is Singapore's national facility for bridging this gap. This centre has built up broad capabilities in membrane (both flat-sheet and hollow-fiber) fabrication at industrial scale, the design, construction and testing of elements and modules, and pilot systems for testing in real-life scenarios. This talk will showcase how we take early stage membrane inventions to commercially viable solutions, with examples of pilot scale testing in the field, and a demonstration scale (1 MGD) plug and play Seawater Desalination Integrated Validation Plant.

Pharmaceutical Waste Management: Advanced Oxidation and Membrane Technology

Yiming ZHAO

Singapore Membrane Consortium

Pharmaceuticals with low biodegradability and high hydrophilicity have been frequently detected in industrial and drinking water streams, thus it is of high significance to explore effective pharmaceutical waste's resource recovery and discharge throughout the drug production and treatment processes, therefore to comply with active pharmaceutical ingredients (API)'s discharge limits. Singapore Membrane Consortium (SG MEM) has gathered valuable problem statements from the leading pharmaceutical industry players, which are related to separation of ingredients from liquid waste, zero liquid discharge, water reuse, protein separation, replacement and reduction of solvent consumption, as well as modular waste treatment systems. To address the current challenges of pharmaceutical discharge and to achieve the useful ingredients' recycling, SG MEM is collaborating with Pharma Innovation Programme Singapore (PIPS), the innovation partner (i.e., IPI Singapore) and the solution provider members from the SG MEM ecosystem to investigate the efficient pharmaceutical waste management techniques. The advanced oxidation processes (AOP) have emerged as a 'polishing' step to be applied to remove recalcitrant COD before proceeding with the tertiary treatment. In addition, integrating AOP with specific downstream membrane technology can potentially increase the pharmaceutical wastewater biodegradability. The updated findings of the AOP with various membrane types are showcased in this poster of the SG MEM discovery series in 2024 to enhance the environmental awareness and provide the insights of potential waste management to the pharmaceutical industry end-users.

Unlocking the Potential of Natural Resources: Current Membrane Research in ITB

Helen JULIAN

Institut Teknologi Bandung

Membrane processing technology is increasingly being utilized across a diverse array of applications. At Institut Teknologi Bandung (ITB), we apply membrane technology for the processing and treatment of natural resources. In this workshop, we aim to share our latest research initiatives. First, we will discuss the application of membrane photobioreactors for the treatment of palm oil mill effluent, which operates on the principle of "zero waste discharge" by transforming waste into valuable products. Second, we will explore the role of membrane technology in the production of an isotonic drink derived from cocoa, offering an alternative to existing products on the market. Lastly, we will present our progress in developing dense membrane distillation systems utilizing Nafion-polypropylene, addressing the challenges of wetting encountered in desalination applications.

Researches on new membranes for green society in Gyeongsang National University

Sang Yong, NAM

Gyeongsang National University

The Membrane Research Group at Gyeongsang National University primarily conducts research aimed at creating a sustainable and greener society through membrane technology. In addition to traditional membrane fabrication studies, our research encompasses the development and mechanisms study of novel membranes based on new materials such as 2D materials. Furthermore, we are focusing on membrane technologies to address climate change, including fuel cells, water electrolysis for green hydrogen production, and solid electrolyte for safe batteries. Our group is also engaged in advanced technologies for capturing carbon dioxide with various membrane methods and converting it to useful materials.

Nanoparticle-Infused Polyelectrolyte Complexes: A New Era in Membrane Technology

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The integration of nanoparticles into polyelectrolyte complexes is a major advancement in membrane technology, enhancing both functionality and efficiency in separation and catalytic processes. These hybrid membranes leverage the structural and charge properties of polyelectrolytes alongside the unique advantages of nanoparticles, such as increased surface area and catalytic activity. This combination allows for precise molecular-level separation and facilitates chemical reactions directly on the membrane surface, minimizing the need for additional catalytic agents. These innovative membranes find applications across various industries, including water purification, chemical processing, and energy production, offering improved performance and sustainability compared to traditional membrane systems. The development of nanoparticle-embedded polyelectrolyte complexes is a transformative step in creating versatile, high-performance membrane technologies. This discussion will focus on polyelectrolyte complex based membrane materials made from carrageenan (κ-CGN/P(Am-co-DMDAAc)-GO) (TA@CGN-LP) and chondroitin sulfate (CS/PAAm-DADMAc/GO), and catalytic membranes prepared from Pebax-CoZn MOF with different surfactants (F127 and PVP), and Pebax-amino-PGMA/GO-WO3/Fe3O4, respectively.

Treatment of recalcitrant pollutants in a dual membrane reactor system: Experimental and Modelling Study

King Lun YEUNG

Hong Kong University of Science and Technology

The treatment of recalcitrant pollutants poses a significant challenge in environmental engineering. This study investigates the efficacy of a dual membrane reactor system for the removal of such pollutants. The research combines experimental analysis with mathematical modeling to assess the performance of the system. The experimental results provide insights into the removal efficiency and kinetics of the pollutants, while the modeling aspect offers a predictive understanding of the system's behavior. The integration of experimental data and modeling techniques enhances our ability to optimize the reactor system for efficient pollutant removal. Overall, this study contributes to the advancement of sustainable solutions for addressing recalcitrant pollutants in wastewater treatment processes.

Impacts of a move toward Nutrients in a Circular Economy

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Increasing population growth and rapid urbanisation is placing increasing pressure on existing water infrastrucuture and agricultural food productivity to meet future supply and demand. The World Bank predicts that by 2050, the global population will be nine billion, placing a 50% increase in agricultural food productivity and 15% increase in water withdrawals. With these fertilise shortages, there is a strong market driver for bioavailable nutrients through a renewable approach. Decentralising the treatment of our wastes is especially interesting as it has the potential of making an industry, notoriously thirsts in energy, water and raw materials, a net producer. It was also demonstrated that the integration of source-separation of urine, faeces and greywater would help to achieve this goal, while also opening new opportunities for building a more flexible and resilient urban wastewater network. Urine valorisation is attractive due to its low volume, high nitrogen (N) and phosphorus (P) concentrations (80% of N and 50% of P inputs into sewers), and relative ease of collection and storage. As such, it has often proven to be a suitable raw material from the production of fertiliser, energy and water (this last one mainly on board of the International Space Station). However, conventional technologies often struggle in dealing with urine alkalinity, high NH3 and dissolved organic carbon concentration (i.e. 5 to 10 g.L-1) and high salinity (i.e. 4 to 9%). That is why, the strong chemical resistance, small footprint, tuneable selectivity and versatility in the operation of processes makes them an ideal technology to extract value from human urine. As such, this presentation will cover four main research themes from the ARC Research Hub for Nutrients in a Circular Economy (ARC NiCE Hub) in terms of economic, commercial, environmental and societal benefits.

Highlights of Research on Sustainable Membrane Fabrication and Membrane-based Agro-Food Processes at the Institute on Membrane Technology (CNR-ITM)

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1. Membrane fabrication toward a more sustainable approach

The awareness of the real risks connected with industrial membrane production sector has been the push towards the search of new, more sustainable, solvents and raw materials. Solvents are the most common example of auxiliary substances for membrane preparation via phase inversion. They are needed for dissolving the selected polymer and their chemical-physical properties strongly influence the membrane formation too. Among the most widely used solvents, DMF, DMAc and NMP represent an excellent choice for dissolving polyvinylidene fluoride (PVDF) and sulfones polymers. However, since they are classified as highly reprotoxic, their use should be avoided whenever possible. Therefore, the use of alternative, less-toxic, diluents for making polymeric membranes open new perspectives for the sustainable membrane fabrication. Herein, the main techniques and properties of solvents to be used in membrane fabrication, and case studies on membrane production via NIPS coupled with VIPS using different innovative non-toxic solvents, such as, dimethyl isosorbide (DMI) and CyreneTM (dihydrolevoglucosenone) is discussed in details.

2. Membrane-assisted biorefinery of agro-food wastewaters and by-products

The valorization of bioactive compounds from agro-food by-products is strongly related to the development of suitable extraction, purification and concentration methodologies. Pressure-driven membrane operations are today well-established technologies in food processing industries. These processes, in relation to their intrinsic properties, have demonstrated to meet the requirements for the recovery, separation and concentration of bioactive molecules also in the treatment of downstream processing streams of the agro-food production contributing to reduce the cost of their disposal and providing new high added-value products for new market trends within the logic of the circular economy. An overview of membrane processes investigated at the CNR-ITM for the recovery of bioactive compounds from different agro-food by-products is given with specific emphasis towards the performance of selected membranes in terms of productivity and rejection of target compounds. Integrated membrane systems, designed for specific wastewaters and by-products, are also illustrated.

Highly stable ion-conducting ceramic membranes for hydrogen purification

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To date, the majority of hydrogen is produced from natural gas and coal. Such fossil-fuel-derived hydrogen must be purified from the common contaminants (for example, CO2, CH4, CO and H2S) for the further applications such as hydrogen fuel cells. In comparison to Pd-based membranes, ceramic membranes with mixed ionic-electronic conductivity have been considered as a promising H2-purification technique owing to its lower investment cost and 100% permeation selectivity. However, it remains challenging to design cost-effective, easily processed membranes with both fast oxygen transport and high chemical stability in practical operating conditions. Following our previous works on the development of a Ti/Ce-based membrane with excellent chemical stability and mixed oxygen ionic-electronic conductivity under reducing atmosphere, inspired by the architectural structure of the rooted grasses in soil, here, we report an interface-reaction-induced reassembly approach for the direct fabrication of Ce0.9Gd0.1O2-δ (CGO) thin layers rooted in the parent multilayered ceramic membranes by only one firing step. The CGO dense layers are very thin (~1 μm), and adhered strongly to the parent support layer, ensuring low ionic transport resistance and structural integrity of the multilayered membranes. When using as an oxygen permeable membrane for upgrading fossil-fuel-derived hydrogen, it shows very long durability in harsh conditions containing H2O, CH4, H2, CO2 and H2S with efficient hydrogen production. Furthermore, our approach is highly scalable and applicable to a wide variety of ion conducting thin layers, including Y0.08Zr0.92O2-δ(YSZ), Ce0.9Sm0.1O2-δ (SDC) and Ce0.9Pr0.1O2-δ (CPO). These results highlight the promise of the novel approach to fabricate high-performance membranes for upgrading fossil-fuel-derived hydrogen, and its potential for other important energy devices such as solid oxide cells, membrane reactors and oxygen sensors.

Recent research activities at Membrane Center of Kobe University

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Research Center for Membrane and Film Technology,
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As the first and only-one university-driven membrane research center in Japan, the Center for Membrane and Film Technology (MaFTech Center) of Kobe University was established in 2007. In 2015, the integrated membrane research building (6000m2) finished its construction and started its operation. Currently we are collaborating with more than 80 industrial companies, as well as partnering 16 academic membrane research centers overseas.
In this presentation, MaFTech center's recent research related to organic solvent reverse osmosis (OSRO) membrane will be introduced. Organic liquid mixtures are frequently produced in numerous industries for example petroleum refining process, and therefore the separation processes used for organic liquid separation play an essential role for product purification. The market currently relies heavily on energy-intensive thermal separation approaches such as evaporation and distillation. However, the continuously increasing industrialization requires more sustainable, efficient, and economical processes.
In my presentation, I introduce the OSRO membranes investigated in our center such as polyamide-based organic membrane, organic membrane spin coated by using a Teflon polymer (AF2400) and newly synthesized copolymer, and inorganic ceramic membrane. The obtained membrane performances will be mentioned.