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Polymer-based membrane technology developed for the separation of volatile organic compounds

German speciality chemicals company Evonik has developed a polymer-based membrane technology for the separation of volatile organic compounds (VOCs).

Launched under the brand PuraMem® VOC it is capable of efficiently separating long-chain hydrocarbons from a natural gas or nitrogen mixture.

The spiral-wound membrane module has been optimised for speciality applications, such as natural gas treatment, emission control in tank farms, and for use in the chemical and process industries. It is distinguished by consistently high selectivity over a long period under demanding operating conditions, says the firm.

According to Evonik, the technology functions on the basis of the different molecular sizes of the substances to be separated. The gas mixture streams through the membrane at a pressure of up to 80 bar (8 MPa), with the larger VOC molecules passing through the membrane whilst the smaller gas molecules are retained. The company is able to adjust this key separation property – the selectivity – at the polymer level.

Dr Goetz Baumgarten, who is the head of the membranes innovation growth field at Evonik, commented: 'Thanks to our many years of expertise in polymer chemistry we are able to adjust the membrane properties already at the development stage of the base material – our high-performance polymer – to produce especially selective and robust membranes that can withstand extreme pressures and temperatures.'

As reported previously, Evonik Performance Materials GmbH, a division of Germany's Evonik Industries AG, is also coordinating a project, involving 24 partners from ten different countries, which aims to develop a new process for catalytic synthesis (*Membrane Technology*, October 2020, page 6).

In other projects, Evonik is also working to close the carbon dioxide cycle through "artificial photosynthesis" and is aiming to make green hydrogen more affordable (see page 8 of this issue).

For further information, visit:
www.evonik.com/puramem-voc

Memsift and Piller work together to establish benchmark for industrial liquid-waste treatment

Memsift Innovations Pte Ltd is working on a project with the Singapore-based operations of Piller Blowers & Compressors GmbH, a German firm that specialises in mechanical vapour recompression (MVR) blowers.

Under a memorandum of understanding (MOU), Memsift and Piller SEA Pte Ltd are working together to develop a prototype industrial liquid-waste treatment system to set up a new benchmark for industrial liquid-waste treatment and zero liquid discharge. This will be achieved by integrating Piller's high-speed MVR blowers VapoFan with Memsift's TS-30™.

Memsift says that its TS-30 system uses a thermal separation process based on a thermodynamic principle and the proprietary membrane STOMATE® to significantly reduce the cost of treating industrial effluent.

To further enhance the energy efficiency of this technology it is integrating it with an energy-efficient sub-system. According to the company, it is advantageous to work with specialist manufacturer to customise the subsystem to fit with its thermal membrane process to reduce the energy consumption to a new level.

Commenting on the agreement, Dr J. Antony Prince, CEO, Memsift Innovations and

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(The content of this newsletter is compiled from a variety of sources, including press releases.)

Fluence's technology is used to upgrade SWRO desalination plant in Egypt

Fluence Corp Ltd has secured a contract worth US$3.2 million through its joint venture International Company for Water Services (IWS) to upgrade a desalination facility in Egypt.

The agreement with a semi-government utility company involves rehabilitating a sea-water reverse osmosis (SWRO) plant in Sharm El Sheikh, which has a capacity of 12 000 m^3 (about 3.2 million gallons) per day. The system, which is expected to be completed and operational by late summer 2021, will provide potable water to several large resorts located in the popular tourist city.

The provider of water and wastewater treatment systems says that the project will use upgraded equipment, implementing its technology, to replace the ageing infrastructure of the current SWRO plant at the site. Fluence's systems will also incorporate an energy-recovery unit that will further improve efficiency.

Commenting on this latest contract, Henry Charrabé, Managing Director and CEO, Fluence, said: 'Securing this project further strengthens Fluence's position as a growing and innovative provider of water treatment systems and products in Egypt.'

'Together with the US$7.6 million NIROBOX™ smart packaged desalination system ordered in October 2018, and its US$20 million order for the New Mansoura desalination plant, awarded in March 2019, this latest contract further reinforces two key elements of Fluence's growth strategy: a focus on desalination systems for geographies urgently addressing water shortages, and providing innovative water technology to help build sustainable communities.'

Fluence is seeing continued expansion of applications worldwide for NIROBOX, further increasing its recurring revenues (*Membrane Technology*, December 2018, pages 6–7). As reported previously, the plant has been deployed in the Philippines and Argentina, and on the island of Mayotte, located off the east coast of Africa, between Madagascar and Mozambique. More recently further contracts have covered a build, own and operate plant in Peru, a build, own, operate and transfer project in the Bahamas and the order from Egypt.

For further information, visit: www.fluencecorp.com

DuPont works with India's Onsitego to launch FilmTec RO elements online

DuPont Water Solutions, a business unit of DuPont Safety & Construction, is working with after-sales services company Onsitego, based in India, to sell FilmTec™ residential reverse osmosis (RO) elements on Amazon, making them available to households across the country.

Onsitego offers an annual maintenance contract (AMC) plan for water purifiers, which comes with a service kit consisting of FilmTec RO membranes from DuPont and filters from other reputed companies.

Customers who buy Onsitego's water purifier AMC service will receive FilmTec RO elements, which will be shipped directly to the customer's residence, and an Onsitego engineer will install or replace the RO membrane.

According to DuPont, homeowners demand clean drinking water – and safe drinking water – that tastes good and can be used for cooking and bathing. Tap water, however, may contain contaminants, such as pesticides and fungicides used in agriculture, organic solvents, trace pharmaceuticals and heavy metals such as arsenic, lead and mercury. It says that RO is amongst the most effective technologies for removing contaminants and disease-causing bacteria and viruses from drinking water.

Speaking about the partnership, Nanette Hermsen, Global Marketing Director, DuPont Water Solutions, said: 'It gives us immense gratification to launch FilmTec elements in AMC kits online in a strategic partnership with Onsitego for India consumers.'

'India consumers have shown a strong inclination towards high-quality products and services, which is why we are very confident about partnering with Onsitego, with its excellent service standards and presence across ecommerce platforms and modern trade stores like Croma and Vijay Sales. With this partnership, RO water purifier owners can enjoy high-quality products with great service delivered to their doorstep.'

Chrys Fernandes, Business Leader, DuPont Water Solutions India, added: As part of our commitment to help make water safer and more accessible for communities and homes around the world, we are excited about this collaboration.'

'In India, this collaboration gives homeowners the opportunity to experience our trusted and innovative water purification technologies along with Onsitego's hassle-free and reliable post-purchase services.'

For further information, visit:
www.dupontwatersolutions.com &
www.onsitego.com

Axium Process invests in machinery to meet increased demand for precision engineering

UK-based Axium Process has invested in further machinery to meet increased demand for high-quality precision manufacturing.

The manufacturer of hygienic process systems, which specialises in cross-flow filtration and separation technology – says that the capital investment enables it to support the pharmaceutics sector with higher volumes of precision engineered components in-house, including one-off designs and batch requirements.

The two new additions to the factory floor include a Doosan Lynx 220 twin-spindle lathe and Doosan DNM5700S vertical milling machine – both of which are computer numerical control (CNC) systems that offer two- and three-dimensional design prototyping, animation and simulation using fusion 360 software.

Axium Process says that this significant investment ensures increased capacity in-house, shortening lead times, increasing design flexibility and enabling quick recall for repeatable machining.

The CNC processes are fully integrated with the business's other services, including design, product development, fabrication and surface finishing – all with full traceability.

For further information, visit:
www.axiumprocess.com

Roark Industries supplies its graphene membranes to India's Nuva Machine Works

Graphene specialist Roark Industries has formed a strategic supply agreement with an engineering company based in India that designs, manufactures and supplies textile machinery and industrial wastewater treatment equipment.

According to Roark Industries, the partnership with Nuva Machine Works India Private Ltd (NMWIPL) covers the supply of its GOGO™ graphene membranes.

Roark Industries recently commercially launched its membranes that are tailored to trap specific elements on separate graphene oxide (GO) layers, based on molecular size (*Membrane Technology*, October 2020, page 1).

This makes them ideal for use in industries that need to recover valuable elements from waste streams. They also deliver a massively cost-efficient alternative to traditional reverse osmosis filtration systems without any degradation in the filtration quality.

A spokesperson for Roark commented: 'We are thrilled to be working with such a high-level supplier in the wastewater and recovery market.'

'We believe that membrane filtration through graphene is the starting point for the true commercialisation of graphene. We are delighted that our ability to produce many hundreds of tonnes of multilayer graphene (MLG) and few-layer graphene (FLG) per annum means that we can deliver an exceptional filtration system at a fraction of the cost of RO and other systems.'

For further information, visit: www.kraor.co.uk &
www.nuvamachine.com

High-purity chemical filters are targeted at the microelectronics industry

Porvair Filtration Group has recently introduced a range of high-purity chemical filters and housings specifically designed for microelectronics applications.

The specialist filtration and environmental technologies group says that LiquiPro™, which complements its GasPro™ (*Membrane Technology*, August 2016, Page 5) range of high-purity filters for gas-handling applications, delivers improved performance within the semiconductor industry by reducing process defects and lowering operating cost.

The products are suitable for the following applications:

- chemical mechanical planarisation (or polishing);
- physical vapour deposition copper plating;
- wet etch cleaning;
- photolithography;
- chemical delivery systems;
- general filtration;
- final cleaning and deionised water filtration;
- plating, etching and stripper chemicals;
- acid, bases and solvents (selected applications); and
- engineering or equipment companies requiring cartridge housings.

The LiquiPro range includes cartridges, capsules and their respective housings. The filters are available as standard cartridges and in disposable or capsule form. Polypropylene polyethersulfone, fluoropolymer, nylon and polyvinylidene fluoride filtration media are all available in a range of pore sizes, says the firm.

For further information, visit: www.porvair.com &
www.porvairfiltration.com

De.mem receives UPW treatment system order and signs BOO contract

De.mem has received an order worth A$400 000 for an ultrapure water treatment (UPW) system. The Australian–Singaporean water and wastewater treatment company also recently signed a build, own, operate (BOO) contract in Singapore, valued at A$800 000.

The company says that the UPW order is significant because it generates its first revenues from the Australian power-generating sector.

Under the purchase order, De.mem is delivering membrane-based water treatment equipment to an Australian power station, where it will be used to produce of ultra-pure, deionised water, required for the power-generating process.

This effectively creates a new range of products and services by the firm for the energy and other industrial sectors which require treated water of the highest quality. De.mem says that it plans to offer equipment of this type as a standard product line to customers from the energy, electronics, semiconductor and other industries.

Andreas Kroell, CEO, De.mem, commented: 'This new contract improves revenue quality by effectively creating a new product

line and expanding our reach into the highly desirable industry segment of power generation, with institutional customers and stable cash flow.'

'The demand from industrial customers for this type of water treatment system is large. We will add this product to our standard product offering going forward, and will further promote it into our industrial customer-base.'

Under the BOO contract, De.mem will build, own and operate a wastewater treatment system that is being deployed on-site at a factory in Singapore run by Givaudan.

This is De.mem's third BOO contract with the company that manufactures flavours, fragrances and active cosmetic ingredients. Under the previous BOO contract – with a minimum value of A$1.7 million – De.mem operates a containerised wastewater treatment system on-site at the firm's factory (*Membrane Technology*, January 2020, page 2)

Kroell continued: 'This contract highlights De.mem's long-standing relationships with high-quality, global institutional clients, with this being our third major project for Givaudan.'

'Our BOO model is a unique offering within the water treatment industry, providing clients with convenience and simplicity, whilst generating recurring, long-term revenues for De.mem. It follows our strategy to build a "one-stop-shop" portfolio of products, technologies and services appealing, in particular, to industrial water and wastewater treatment clients.'

For further information, visit:
www.dememembranes.com

Saltworks ships targeted ion treatment plant to US mining client

Saltworks Technologies Inc reports that it recently shipped a full-scale, cost-optimised, targeted ion treatment plant to a client based in the USA which operates in the mining sector.

The Canadian company, which develops technology for industrial desalination, brine treatment and zero liquid discharge (ZLD), supplied the BrineRefine equipment despite potential difficulties caused by COVID-19.

According to the firm, its essential workers – engineering, production and supply chain – are doing an exemplary job keeping its factory running safely and with minimal disruption during the ongoing pandemic.

Saltworks says that it was originally contacted by the mining firm because of its expertise in ultra-high recovery reverse osmosis (RO). However, it was realised that a simpler, lower cost system would be a better fit for its client's treatment needs. Rather than treat all ions in the water – the way in which RO does – the BrineRefine plant targets specific ions-of-concern through the firm's IonSelect technology.

The result is no RO-brine liquid waste to manage. Instead, a small mass of residuals is generated that can be easily handled on-site. It also means lower capital and operating costs because the core problem is "surgically" targeted, as opposed to treating the entire flow.

Earlier this year, we reported that Saltworks had developed a membrane-based brine concentrator that makes extensive use of reverse osmosis (RO) technology. In addition, it had started commissioning the plant – believed to be the first of its kind – that minimises the volume of brine sent to disposal or processed by more costly thermal technologies (*Membrane Technology*, February 2020, pages 1–2).

For further information, visit:
www.saltworkstech.com

VWT subsidiary supplies SWTI system for use on FPSO

Yinson, a Malaysia-based provider of floating, production, storage and offloading (FPSO) services, recently awarded a contract to Veolia Water Technologies (VWT) – through its subsidiary VWS Westgarth Ltd – covering the supply of a sea-water treatment and injection (SWTI) system for the Anna Nery FPSO.

The SWTI, which involves two integrated process modules, is capable of delivering 38 000 m^3 (around 10 million gallons) per day of treated sea water for enhanced oil recovery water-flood injection.

At the heart of the process is membrane-based technology for sulphate removal. Removing sulphates from the injected sea water protects the oil reservoir against barium and strontium sulphate scaling and reservoir souring.

According to Veolia, this SWTI contract for the FPSO Anna Nery is its first contract with Yinson.

For further information, visit:
www.veoliawatertechnologies.com,
www.veolia.com & www.yinson.com

Ecolab and Anios double the capacity of their centre of excellence in France

Ecolab Inc – a supplier of water, hygiene and energy technologies and services to the food, energy, healthcare, industrial and hospitality markets – and Laboratoires Anios, an Ecolab company that focuses on the healthcare sector, have expanded their Luce Letartre Research Center in Sainghin-en-Mélantois, in the north of France.

The 2000 m^2 (21 500 ft^2) centre doubles the site's research and innovation capacity, and will help accelerate the ability to develop technology and products for infection prevention in the healthcare sector.

Ecolab says that the facility is the only research centre in Europe to integrate dedicated laboratories for chemistry formulation, microbiology, analytical chemistry and virology, the latest addition to the group's capabilities.

Equipped with the latest technology, it can develop hygiene and infection prevention products to fight infections in a healthcare setting and demonstrate the effectiveness of the product portfolio on all types of bacteria, viruses, fungi, yeasts and other emerging micro-organisms that could be present in a hospital environment.

The entire research centre has dual GLP and ISO: 17025 certifications, contributing to its international recognition and compliance.

'This centre of excellence has capacity and capabilities that are unmatched in Europe,' commented Chafik Hilal, the general manager of Ecolab Europe's healthcare division.

'This expansion supports our growth ambitions, combining the scientific and commercial expertise of Ecolab and Anios to help hospitals eradicate healthcare-acquired-infections and protect public health.'

For further information, visit:
www.ecolab.com &
www.anios.com

ZeeLung technology shows its ability to quickly, easily and cost-effectively upgrade existing WWTPs

Edited by Simon Atkinson

Technology from SUEZ that maximises treatment capacity in existing tank volumes at wastewater treatment plants (WWTPs) – whilst also reducing energy consumption – is being used to upgrade a facility in Ontario, Canada. This focus article provides an insight into what is involved and the benefits gained.

The Region of Waterloo, in southwestern Ontario, has selected SUEZ's ZeeLung technology to equip what is believed will be the largest membrane aerated biofilm reactor (MABR) system in the world.

Currently being installed at the Hespeler Wastewater Treatment Plant, the technology will support the regional government's objectives to deliver better water quality whilst improving nutrient removal, reducing energy and maximising the treatment capacity and performance from existing assets, says SUEZ.

The Region of Waterloo serves a total population of more than 600 000 people, using its 13 wastewater treatment plants to process 180 million litres (47.6 million gallons) of wastewater per day.

To meet the projected population growth, the secondary treatment process of the Hespeler plant has to be upgraded. The contract follows an eight-month pilot that demonstrated the ZeeLung technology and refined the design for full-scale implementation.

When commissioned in 2021, the upgrade of 9.34 million litres (2.46 million gallons) per day will be the largest implementation of MABR technology in the world, claims SUEZ.

Upgraded quickly and easily

'This is a first-of-its-kind project for Canada that will demonstrate ZeeLung's benefits: the ability to quickly and easily upgrade existing wastewater treatment plants on a cost-effective basis, with little disruption to on-going operations,' explained Kevin Cassidy, Executive Vice President Engineered Systems, Water Technologies & Solutions, SUEZ.

'ZeeLung technology is used to upgrade conventional activated sludge plants for nutrient removal and capacity expansion.'

'The technology enables customers to increase the treatment capacity of their plants, for a better water quality, in a compact footprint whilst also reducing energy consumption.'

Gas permeable media

ZeeLung technology is used to upgrade conventional activated sludge plants for nutrient removal and capacity expansion.

It uses gas permeable media to deliver oxygen to a biofilm that is attached to the media surface. Oxygen is delivered through the media by molecular diffusion, which is done without the use of bubbles. In conventional wastewater treatment, 60% of the energy used is consumed by blowers that deliver bubbles to provide the oxygen necessary for the biological process.

With ZeeLung technology, oxygen is delivered without bubbles, which reduces the energy required for oxygen transfer by up to four times – this enables facilities to significantly reduce their energy footprint whilst also increasing capacity and improving treatment quality.

For further information, visit: www.suezwatertechnologies.com/products/biological/zeelung & www.suez.com

Looking back at various applications

In 2017, French environmental services company SUEZ, together with Canadian long-term institutional investor Caisse de dépôt et placement du Québec (CDPQ), acquired GE Water & Process Technologies (GE Water) in a deal worth €3.2 billion (*Membrane Technology*, November 2017, page 1). In doing so it also acquired the ZeeLung technology.

Membrane Technology first covered ZeeLung systems in an article entitled 'ZeeLung technology developed to enable wastewater treatment plants achieve energy neutrality, which appears in *Membrane Technology*, January 2016 (pages 7–8).

Further coverage of this technology includes:

- 'GE technologies help plant meet latest total nitrogen removal regulations' (*Membrane Technology*, August 2017, pages 4–5);
- 'MABR increases treatment capacity within existing plant footprint' (*Membrane Technology*, May 2017, page 6); and
- 'Demonstration highlights ZeeLung MABR's potential' (*Membrane Technology*, March 2017, page 8).

(This news focus is based on press material issued by Water Technologies & Solutions, SUEZ.)

Singapore's first large-scale dual-mode desalination plant is now on stream

Edited by Simon Atkinson

Keppel Marina East Desalination Plant – Singapore's fourth desalination plant and the island city-state's first large-scale, dual-mode desalination facility – is now up and running. Over three years ago Keppel Infrastructure Holdings Pte Ltd and national water agency PUB unveiled the innovative design for the facility at a ground-breaking ceremony conducted at the Marina Barrage (*Membrane Technology*, July 2017, pages 1 & 16). This article provides an update to previous coverage of this major project.

Following a series of tests and commissioning, Singapore's fourth desalination plant, the Keppel Marina East Desalination Plant (KMEDP), commenced commercial operations mid-2020.

Operated by Marina East Water Pte Ltd (Marina East Water), a wholly-owned subsidiary of Keppel Infrastructure Holdings Pte Ltd (KI), the large-scale, dual-mode facility is the first of its kind in Singapore, with an innovative design, situating treatment equipment completely underground and featuring a lush green rooftop for community recreation.

KI, a wholly owned subsidiary of Keppel Corp Ltd (a leading company listed on the Singapore Exchange) drives the Keppel Group's strategy to invest in, own and operate competitive energy and environmental infrastructure and services.

Under the design, build, own and operate (DBOO) arrangement with PUB, Marina East Water has undertaken plant operations for a concession period that spans 25 years – from 2020 to 2045.

Sea water or fresh water

The dual-mode desalination plant is capable of producing 137 000 m^3 (about 30 million gallons) of fresh drinking water per day.

It is the second water plant developed and operated by Keppel under the DBOO arrangement – the first being the Keppel Seghers Ulu Pandan NEWater Plant.

KMEDP's location in Marina East gives it the ability to treat either sea water or fresh water that is drawn from the Marina Reservoir, depending on the prevailing weather conditions.

According to PUB, this will strengthen Singapore's water supply resilience in the face of increasingly dry weather conditions caused by climate change. In dry weather, the plant will draw water from the sea to produce desalinated water. Alternatively, when it rains, it will use rainwater collected in the reservoir to produce potable water, which requires less energy and fewer steps in the treatment process, compared with desalination.

Practically limitless source

Ng Joo Hee, Chief Executive, PUB, said: 'Seawater desalination is one of Singapore's "four national taps". Unlike the other three taps – imports, rainfall and recycled water – it is a practically limitless source.'

'The ocean is almost infinite. It is also weather-resistant and always available, rain or shine, as a source of life-giving water. The availability of desalination makes Singapore's water supply immensely resilient. And the KMEDP coming online further strengthens Singapore's water security.'

Sustainable urbanisation

Dr Ong Tiong Guan, CEO, Keppel Infrastructure, added: 'We are pleased to have commenced operations for the iconic KMEDP. As a provider of technology for sustainable urbanisation, Keppel is proud to support PUB in securing Singapore's water supply. KMEDP will also contribute to the group's recurring income stream, bolstering its ability to create long-term value for stakeholders.'

Dr Guan says that completing the final lap of testing and commissioning during the Covid-19 pandemic brought about some inevitable challenges, because of the reduced personnel. Keppel worked closely with PUB and its contractors to overcome these challenges and deliver a successful project.

Stunning backdrop and design

The plant is set against the stunning backdrop of Singapore's Central Business District skyline, along the cyclist-friendly Eastern Coastal Park Connector Network that bridges the recreational spaces of East Coast Park and Gardens by the Bay East.

It also incorporates environment-friendly elements within its landscaping, such as rainwater harvesting ponds and storm-water management systems, to retain rainwater for reuse in irrigation and the facility's water features.

The plant is recognised for its sleek, modern design that breaks away from those of conventional water treatment plants and is the first industrial plant to achieve such seamless integration with the surrounding greenery, says PUB.

It achieves multiple land uses by situating treatment facilities underground. These can be seen by visiting the private viewing gallery. This approach frees up nearly 20 000 m^2 (around 215 280 ft^2) of open green rooftop space for community activity and recreation. This "green roof" also reduces the urban heat island effect.

Gold certification

In October 2019 KMEDP became the first industrial plant in Singapore to be awarded the ABC Waters Certification (Gold) by PUB in recognition of its outstanding design features and exceptional Active, Beautiful, Clean (ABC) standards.

Launched in 2010, PUB's ABC Waters Certification Scheme, recognises developers who incorporate ABC Waters design features in their developments.

The Gold category is the highest obtainable accolade, awarded to projects with outstanding designs and elements, such as community space, water features, greenery and sustainable water management systems integrated within them.

For further information: www.pub.gov.sg & www.kepinfra.com

(This news focus is based on press material issued by PUB.)

Ultra-thin membrane is capable of producing more energy from sea water than ones currently used

Edited by Simon Atkinson

This article briefly describes the development of a nanoporous carbon membrane that is similar to graphene. The scientists behind the research done at Leiden University, in The Netherlands, say that this ultra-thin material, which is only 2 nm thick, is capable of producing about a hundred times more power from sea water than the best membranes used today.

When fresh water and salt water meet, an exchange of salt and other particles takes place. A membrane placed in water is able to harness energy from particles that are moving from one side of its structure to the other. A similar process also can be used to desalinate sea water.

Researchers at Leiden University have developed a membrane which, they say, can produce a hundred times more energy than classic membranes and known prototype membranes in scientific literature.

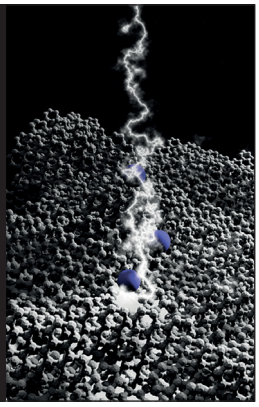
Thin and porous

The amount of power that is generated depends on the thickness of and porosity of the membrane.

The chemists were able to create a carbon-based membrane that is both porous and thin, which is why it can produce more energy than current membranes that are either porous or thin, but not both.

To create this membrane, Dr Xue Liu and Dr Grégory Schneider, Leiden Institute of Chemistry, spread a large number of oily molecules on the surface of water. On their own these molecular "building blocks" then form a thin film. By heating the film, the molecules are locked in place, creating a stable and porous membrane.

According to Liu, the membrane can be adapted for specific requirements. He explained: 'The membrane we have created is only 2 nm thick and permeable to potassium ions. We can change the properties of the membrane by using a different molecular building block – that way we can adapt it to suit any need.'



The researchers from Leiden report a bottom-up approach to synthesise a nanoporous, ultra-thin carbon membrane which is cation-selective. The membrane can efficiently convert salinity gradient energy into electricity, with an output power density of 67 W/m^2 *(image courtesy of Dr Xue Liu).*

Similar to graphene

The carbon membrane is similar to graphene – a large flat membrane made up of only carbon atoms. However, Schneider says that this new membrane is in a whole different category.

He commented: 'When making a membrane, a lot of researchers start out with graphene, which is very thin, but not porous. They then try to punch holes in it to make it more permeable.'

'We have done the reverse by assembling small molecules and building a larger porous membrane from those molecules. Compared with graphene it contains imperfections, but that is what gives it its special properties.'

This new membrane combines the best of both worlds.

'Much of the research in this field was focused on creating better catalysts, membranes were somewhat of a dead end. This new discovery opens up whole a range of new possibilities for power generation, desalination and for building much more efficient fuel cells,' added Dr Schneider.

For more information: Dr Grégory Schneider, Associate Professor, Leiden Institute of Chemistry, Leiden University
Email: g.f.schneider@chem.leidenuniv.nl
www.universiteitleiden.nl/en/science/chemistry

(This technology focus is based on press material issued by Leiden Institute of Chemistry, Leiden University.)

(Further details of this research are presented in a paper entitled 'Power generation by reverse electrodialysis in a single-layer nanoporous membrane made from core–rim polycyclic aromatic hydrocarbons', which appears in *Nature Nanotechnology*, Volume 15, pages 307–312 (2020), DOI: https://doi.org/10.1038/s41565-020-0641-5.)

Recent coverage of graphene and related materials

In addition to the research described in the main text, membrane technology based on nanoporous graphene and related atomically thin layered materials, is frequently covered in this newsletter.

Below is a brief list of selected articles:

- 'Graphene-based membranes are tailored to trap specific elements on separate layers' (*Membrane Technology*, October 2020, page 1);
- 'NGI works with UK firm to develop enhanced water filtration system based on graphene's unique properties' (*Membrane Technology*, July 2019, page 5);
- 'Graphene research yields atomic-scale capillaries small enough to block the smallest ions' (*Membrane Technology*, April 2019, pages 8 & 9); and
- 'Electrical current precisely controls water flow through graphene smart membranes' (*Membrane Technology*, November 2018, pages 9–10).

Evonik works to close carbon dioxide cycle through "artificial photosynthesis" and aims to make green hydrogen more affordable

Edited by Simon Atkinson

We recently reported that Germany's Evonik Industries AG is continuing to strengthen its position as one of the leading companies in the field of C4 chemistry by playing a pivotal role in the 'Membranes and Catalysts Beyond Economic and Technological Hurdles' (MACBETH) project (*Membrane Technology*, October 2020, page 6). In the article that appears here we look at another project in which Evonik is involved, which aims to develop a climate-friendly process based on what is referred to as "artificial photosynthesis". This uses carbon dioxide and hydrogen as raw materials for the sustainable production of chemicals. Separately, we also explain how the company, in another venture, is turning to membrane technology to help it make green hydrogen more affordable.

Evonik and Siemens Energy recently commissioned a pilot plant in Germany that uses carbon dioxide (CO_2) and water to produce chemicals. The electricity needed to power the plant comes from renewable resources.

Sponsored by the German Federal Ministry of Education and Research or (Bundesministerium für Bildung und Forschung – abbreviated BMBF), the pilot plant is located in Marl, in the northern Ruhr area of the country, where Evonik's largest site is based.

According to the companies, the innovative "artificial photosynthesis" technology on which it is based should contribute to the success of the energy revolution. It is an essential part of the Rheticus I and Rheticus II research projects, which are receiving funding of €6.3 million from the BMBF.

The Rheticus research project is a spin-off of the Copernicus projects, one of the largest research initiatives of the German Federal Government on energy system transformation. Rheticus demonstrates how the Power-to-X idea – which involves various methods for converting electrical energy into liquid or gaseous chemical energy sources through electrolysis and further synthesis processes – can be successfully put into practice, says Evonik.

Artificial photosynthesis

For the idea of artificial photosynthesis – the underlying technology which is behind the Rheticus experimental facility – the researchers used nature as their model.

In a similar way to which plants use solar energy to produce sugar from CO_2 and water in several steps, artificial photosynthesis uses renewable energy to produce valuable chemicals from CO_2 and water through electrolysis with the help of bacteria.

This type of artificial process can serve as an energy store, which means that it helps to close the carbon cycle and reduce CO_2 in the atmosphere.

Making climate protection possible

'Climate protection is not possible without chemistry, because our industry supplies and develops technology for energy turnaround. Research projects such as Rheticus are a motivation and innovation driver for a sustainable society,' commented Harald Schwager, Deputy Chairman, Executive Board of Evonik and who is responsible for chemicals and innovation at the company.

However, at the same time, Schwager warns against speed when phasing out fossil fuels: 'Security of supply and reliability in political decisions set the framework in which new things are created,' he said.

Christian Bruch, CEO, Siemens Energy, added: 'Our goal is to use innovative technologies to enable new, more sustainable materials and products. With our hydrogen and CO electrolysis, we are building a bridge from green electricity to sustainable materials applications. The close cooperation between politics, science and business partners, like Evonik, is an important step in this direction.'

Pilot plant

The pilot plant comprises a carbon monoxide (CO) electrolyser, developed by Siemens Energy, and a water electrolyser and bioreactor based on Evonik's technology.

In a first step, using electrolysers powered by electricity, CO_2 and water are converted into CO and hydrogen (H_2). This synthesis gas is used by special microorganisms to produce speciality chemicals, initially for research purposes. For example, these are starting materials for special plastics or food supplements.

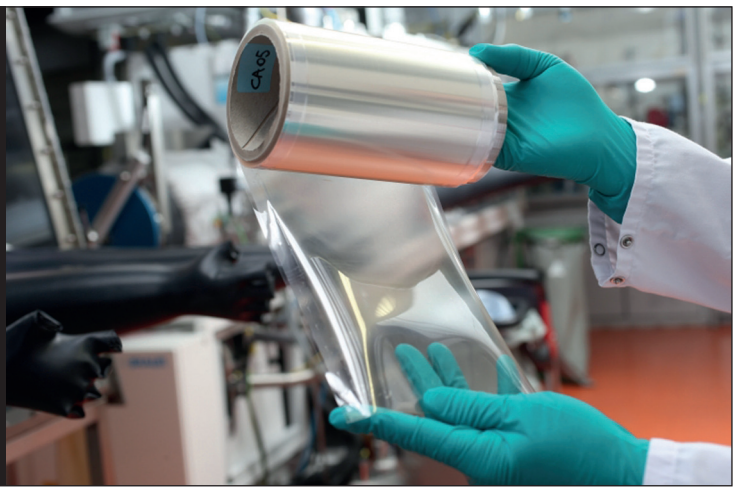
'….artificial photosynthesis uses renewable energy to produce valuable chemicals from CO_2 and water through electrolysis…'

In the coming weeks, the composition of the synthesis gas and the interaction between electrolysis and fermentation will be optimised. In addition, a unit for processing the liquid from the bioreactor will be set up to obtain pure chemicals.

Platform technology

Evonik and Siemens Energy say that after the successful completion of the current Rheticus project phase (Rheticus II) they will have a unique platform technology at their disposal.

This can be used to produce energy-rich and valuable substances such as speciality chemicals or artificial fuels from CO_2 – in a modular and flexible manner.



The polymer chemistry behind the anion exchange membrane developed by Evonik is the key to efficient water electrolysis *(photograph courtesy of Evonik Industries AG).*

Making green hydrogen more affordable

Green hydrogen is efficient and completely sustainable. It is predicted that this gas will be the fuel of the future – both as a carbon-free fuel for industry and transportation. It also has the potential to be a key raw material for the chemicals industry.

Considering green hydrogen's many advantages, Evonik is also investigating ways of making this gas more affordable.

'The polymer chemistry behind this membrane is the key to efficient electrolysis. And we now hold that key.'

It is produced from water by electrolysis using electricity generated from renewable resources. This means that it is still much more expensive than conventional hydrogen, which is generally obtained from methane gas in a process that releases CO_2.

Membrane-based electrolyser

In addition to sufficient low-cost electricity, generated from renewable resources, investment in electrolyser technology is a key factor in the cost-efficient production of green hydrogen, says Evonik.

The central component of the electrolyser, which has a major influence on efficiency and reliability, is an ion-conducting membrane. The company is working on a novel anion exchange membrane (AEM), which enables the cost-efficient production of green hydrogen. The scale-up of the membrane, and the manufacturing technology from lab to pilot and technical scale is planned for the coming years.

The membrane, developed by researchers at Creavis, Evonik's strategic innovation unit, and experts from the firm's High Performance Polymers unit is based on a resistant polymer with excellent conductivity.

'Our membrane could allow commercial realisation of highly efficient and economically viable electrolysis technology. The polymer chemistry behind this membrane is the key to efficient electrolysis. And we now hold that key,' said Oliver Conradi, who is working on membrane research at Evonik.

According to Evonik, electrolysis that employs anion exchange membranes has clear benefits compared with other electrolytic processes, such as conventional alkaline electrolysis using diaphragms (AEL), or the more recent method of proton exchange membrane electrolysis (PEM), which is highly dependent on raw materials such as precious metals.

The AEM concept reduces investment costs because the cells used for electrolysis in alkaline conditions do not require precious metals. Therefore, materials that are less expensive can be used. Other attributes of this AEM electrolysis platform are high current density, very good efficiency and high flexibility.

CHANNEL project

The CHANNEL (*C*ost-efficient *h*ydrogen production unit based on *anion* exchange membrane *el*ectrolysis) project has been established to further the development of the AEM technology.

It comprises a consortium of partners from industry and research organisations that are planning, constructing and testing an AEM electrolysis system based on the new membranes from Evonik.

The project will run for three years and is receiving funding of around €2 million from the European Union's Horizon 2020 research programme.

The consortium covers the entire value chain for the production of green hydrogen. In addition to Evonik, which is providing the AEM membrane, the other project partners are Shell, The Netherlands (hydrogen user); Enapter, Italy (plant engineer for the electrolyser); Forschungszentrum Jülich, Germany (R&D on membrane-electrode assemblies); the Norwegian University of Science and Technology, Norway (catalysts); and SINTEF, Norway (an independent research organisation that is responsible for project coordination).

For further information, visit: www.evonik.com, www.siemens-energy.com, www.bmbf.de/en/index.html, https://ec.europa.eu/programmes/horizon2020/en, https://cordis.europa.eu/project/id/875088 & https://www.sintef.no/en

(This technology focus is based on press material issued by Evonik Industries AG.)

Natural gas processing

Membrane technology developed Evonik is also being used in other areas, as reported previously in the pages of this newsletter.

The article entitled 'Evonik develops membrane for processing natural gas efficiently' (*Membrane Technology*, October 2018, page 9) looks at SEPURAN® NG, which is described by the company as an especially selective and robust hollow-fibre membrane that is based on a high-performance polymer that can withstand extreme pressure and temperatures.

This enables particularly selective separation of the sour gases from natural gas, high tolerance of the higher hydrocarbons contained in the natural gas and consistently high performance of the membrane throughout its service life, says the company.

In 2018, Evonik and gases and engineering company The Linde Group concluded an exclusive cooperation agreement covering the use of membranes for natural gas processing (*Membrane Technology*, August 2018, page 14)

The companies are jointly promoting membrane technology – Evonik on the membrane and polymer side, whilst Linde's Engineering Division is the system integrator for complete membrane package units.

Evonik's established membrane technology is serving as the basis for a jointly developed product described as a high-performance membrane package unit, which is marketed by Linde as "HISELECT™ powered by Evonik".

RESEARCH TRENDS

Membrane wettability for the treatment of saline water using MD

Membrane distillation (MD) is an alternative membrane technology that offers the capacity to treat highly saline water, including industrial wastewater, sea water, brine from other processes, and oil-gas field produced water. However, conventional hydrophobic membranes suffer fast wetting and severe fouling, especially when low surface tension chemicals exist in the saline water, which compromises the performance of MD. Recent advances in material science and nanomaterials research have led to a way of incorporating special wetting properties into a membrane's surface. Membranes with special wettability can be highly resistant to membrane fouling and wetting, and overcome the trade-off between membrane permeability and selectivity. This review summarises the progress and recent development of studies on MD membranes with special wettability. Firstly, the fundamental concepts pertaining to membrane surface wettability – including insights into their benefits and potential issues – are highlighted. Secondly, fabrication methods and applications of membranes using various, special wettability are discussed in detail, along with their challenges. Finally, this review concludes with the advantages of membranes with special wettability and demonstrates potential solutions to the challenges mentioned earlier for future research into high saline wastewater treatment.

M. Yao, L.D. Tijing, G. Naidu, S.-H. Kim, H. Matsuyama, A.G. Fane and H.K. Shon:
Desalination, Volume 479, 114312, (1 April 2020).
https://doi.org/10.1016/j.desal.2020.114312

Enhanced antifouling and flux performance of TFC FO membranes by constructing a support coated with CNTs

In this work, researchers fabricate a support to which is applied a coating made from a sandwich-like structure of single-walled carbon nanotubes (SWCNTs). This was used to prepare a high-performance antifouling thin-film composite (TFC) forward osmosis (FO) membrane. This sandwich-like support was prepared through the deposition of polydopamine modified SWCNTs (PDA-SWCNTs) on both sides of a polyethersulfone (PES) microfiltration (MF) membrane. The top layer of the CNTs was found to facilitate the formation of the polyamide layer. The back layer of the CNTs provided an antifouling surface for the prevention of foulants adsorption and intrusion into the PES support. Results demonstrate that the CNT backlayer imparted superior rejection towards bovine serum albumin (BSA) (about 98.1%) and enhanced hydrophilic properties. The TFC FO membrane (TFC-modified), with the sandwich-like SWCNT-coated support, exhibited excellent permselectivity, with water flux J_w of 35.7 Lm^{-2} h^{-1} and reverse salt flux J_s of 1.42 gm^{-2} h^{-1}, when tested in the mode with the active layer facing the draw solution (AL–DS), (using 1 M NaCl as a draw solution). Dynamic fouling experiments confirm that the TFC-modified membrane possessed effective antifouling performance with a low relative fouling degree (RFD) of 19.0% during the cross-flow run and 8.4% during the BSA adsorption test, which were much lower than the corresponding values of 36.1% and 15.4% for the TFC-control membrane.

L. Deng, Q. Wang, X. An, Z. Li and Y, Hu:
Desalination, Volume 479, 114311, (1 April 2020).
https://doi.org/10.1016/j.desal.2020.114311

Pulse Flow RO – new RO technology targeted at wastewater and brackish water applications

A process referred to as Pulse Flow Reverse Osmosis (PFRO^{TM}) is being developed by the authors of this paper. It is described as a new, innovative method for operating RO water-reuse systems that enables high recovery, high flux and chloramine-free operation. PFRO constantly changes the osmotic and hydraulic conditions, and in doing so greatly diminishes biofouling and scaling, claims the researchers. PFRO technology was demonstrated in a municipal wastewater (WW) treatment facility at Pismo Beach, California, USA, from October 2018 to October 2019, using secondary effluent of a municipal wastewater plant as source water. The unit operated with an average flux of 16.5 gfd (28 lmh) – 50% higher than the standard design of 11 gfd (18–19 lmh). Specific flux was 0.12 GFD/PSI – about 25% higher than most well run wastewater reuse facilities that operate at the same recovery, with specific flux of 0.09–0.1 gfd/psi. The unit operated at 86% recovery in a single RO stage. No chloramine was dosed, which means that no disinfection byproducts were formed. The chloramine-free operation generates permeate with an ultraviolet transparency (UVT) value of about 100%, which saves 30–40% on capital and operational expenditure in the final ultraviolet/advanced oxidation process (UV/AOP) stage. The overall water cost in this process is 14–28% lower than that of a similar standard, fully advanced treatment (FAT) water reuse process.

B. Liberman, L. Eshed and G. Greenberg:
Desalination, Volume 479, 114336, (1 April 2020).
https://doi.org/10.1016/j.desal.2020.114336

Perspectives on advanced and new membrane materials and manufacturing processes

State-of-the-art of membrane technology is characterised by a number of mature applications, such as sterile filtration, haemodialysis, water purification and gas separation, and many more niche applications of successful membrane-based separation and processing fluid mixtures. The membrane industry is currently employing a portfolio of established materials – mostly standard polymers or inorganic materials (not originally developed for membranes), and easily scalable manufacturing processes such as phase inversion, interfacial polymerisation and coating. Innovations in membranes and their manufacturing processes must meet the desired intrinsic properties that determine selectivity and flux, for specific applications. However, features such as a tunable and stable performance, together with sustainability over the entire service life of membrane products, are becoming increasingly important. Membrane manufacturers are progressively required to share with their customers the carbon footprint of their membrane modules. Environmental awareness amongst the world's population is a growing phenomenon and finds its reflection in product development and manufacturing processes. In membrane technology it is possible to see initial steps in this direction with the replacement of hazardous solvents, the use of renewable materials for membrane production and the reuse of membrane modules. Other examples include increasing the stability of organic membrane polymers and lowering the cost of inorganic membranes. In a long-term perspective, many more developments in materials science will be required for making new, advanced membranes. These include "tools", such as self-assembly or micro-fabrication and nano-fabrication, and "building blocks", for example, tailored block copolymers or one-, two and three-dimensional materials. Such mem-

branes must be fabricated in a simpler manner and be more versatile than existing ones. In this perspective paper, a vision of such "LEGO-like" membranes, with precisely adjustable properties, is illustrated with, where possible, examples that already demonstrate feasibility. These include the possibility to switch properties using an external stimulus, adapting a membrane's selectivity to a given separation, or providing the ability to assemble, disassemble and reassemble the membrane on a suitable support as a scaffold – *in situ*, in place and on-demand. Overall, it is foreseen that the scope of future membrane applications will become much wider, based on improved existing membrane materials and manufacturing processes, and on the combination of novel, tailor-made building blocks and tools for the fabrication of next-generation membranes tuned to specific applications.

S.P. Nunes, P.Z. Culfaz-Emecen, G.Z. Ramon, T. Visser, G.H. Koops, W. Jin and M. Ulbricht:
J. of Membrane Science,
Volume 598, 117761, (15 March 2020).
https://doi.org/10.1016/j.memsci.2019.117761

Perfluorinated polymers as membrane materials for gas and vapour separation

Amorphous glassy perfluorinated polymers have attracted attention in membrane science because of their high gas permeability, large free volume and the possibility of using them efficiently for gas separation. An investigation of perfluorinated polymers with various chemical structures has revealed different relationships between structure and transport properties than those known for common, hydrocarbon-based polymers. Atypical hydrocarbon solubility properties and deviations from regular solution theory result in their plasticisation resistance and improved selectivity, when applied to the separation of several gas mixtures. In this review, the authors present information on structure and properties of perfluorinated polymers, discuss their gas and vapour permeation parameters, and peculiarities of their sorption thermodynamics and free volume, and report on their practical application as membrane materials.

Y. Yampolskii, N. Belov and A. Alentiev:
J. of Membrane Science,
Volume 598, 117779, (15 March 2020).
https://doi.org/10.1016/j.memsci.2019.117779

Use of low-dimensional carbon membrane materials in desalination and gas separation

The widespread use of low-dimensional carbon membrane materials for desalination and gas separation is limited by the difficulty to physically realise such membrane designs on a meaningful scale. This review aims to bring together results achieved in this field. The aim is to inspire new designs or developments that could bridge this technical challenge. The focus of this paper is on sub-nanometer separation processes such as desalination or gas separation. This is because such operations consume the most energy, which means that there is much interest in reducing associated costs. Three groups of low-dimensional carbon materials are considered: graphene, carbon nanotubes (CNTs) and graphene oxide (GO). Graphene and CNT membranes have the advantage of high permeability, but are difficult to manipulate to form membranes that are efficient. GO, on the other hand, has the advantage of ease of fabrication, but suffers in terms of separation performance. This paper provides a review of innovative ideas proposed for low-dimensional carbon membrane materials, deliberating their strengths and weaknesses, in a consolidated effort to generate new ideas for further advancements.

E.Y.M. Ang, W. Toh, J. Yeo, R. Lin, Z. Liu, K.R. Geethalakshmi and T.Y. Ng:
J. of Membrane Science,
Volume 598, 117785, (15 March 2020).
https://doi.org/10.1016/j.memsci.2019.117785

Emerging thin-film composite membranes for reverse osmosis

Thin-film composite (TFC) membranes are at the heart of reverse osmosis (RO) processes for desalination and water reuse. In recent years, nanomaterials with high permeability, selectivity and chemical resistance, and low fouling tendency have begun to emerge and to be applied in many other fields. This has stimulated research into novel RO membranes that consist of nanomaterials (non-porous and porous) in their selective layers. Encouraging results have been demonstrated. This paper looks at developments in polyamide thin-film nanocomposite (TFN) membranes for RO processes. These are summarised since the concept of the TFN was introduced in 2007. Whilst it is obvious that nanomaterials could impart exclusive properties, it also should be noted that significant challenges still exist for research and commercialisation of TFN membranes, such as the selection of proper nanomaterials, preventing the leaching of nanoparticles, and performance and cost analysis, before large-scale RO membrane manufacturing. Future research directions are outlined to offer an insight into the fabrication of advanced TFN membranes with optimal interface morphology and separation performance.

D.L. Zhao, S. Japip, Y. Zhang, M. Weber, C. Maletzko and T.-S. Chung:
Water Research, Volume 173, 115557,
(15 April 2020).
https://doi.org/10.1016/j.watres.2020.115557

Evaluation of long-term performance of a continuously operated FCDI system for salt removal from brackish water

Whilst flow-electrode capacitive deionisation (FCDI) – one of the most popular CDI variants – possesses a number of advantages over conventional fixed-electrode CDI (for instance, large salt adsorption capacity, high flow efficiency and convenient management of the electrodes), challenges remain in constructing an FCDI system that it is capable of operating continuously. In this paper, the researchers claim that they achieved effective continuous removal of salt from a brackish feed-stream using flowing carbon electrodes which are regenerated in a closed-loop manner by using an integrated FCDI/MF strategy that they introduced previously. The performance of the FCDI/MF system is characterised over a two-week period of operation, with key factors influencing the desalination performance identified. The results show that the FCDI/MF system is capable of continuously desalinating brackish water (around 2 g L^{-1}) to portable levels (less than 0.5 g L^{-1}) whilst sustaining an extraordinary water recovery rate (about 92%) and relatively low energy consumption (approximately 0.5 kWh m^{-3}). No obvious deterioration in performance or membrane fouling was observed during the fourteen-day period of operation. Whilst the carbon particles used in the flow electrode exhibited only a minor increase in oxygen-containing groups (over the 14 days of operation), a significant reduction in particle size was observed. This is likely to be caused by the high-frequency collisions and associated friction between particles that occur in the FCDI/MF system. Further studies regarding electrode optimisation, cell configuration design and process modelling are needed in order to realise the scale-up and practical implementation of this emerging technology, say the researchers.

C. Zhang, L. Wu, J. Ma, M. Wang, J. Sun and T.D. Waite:
Water Research, Volume 173, 115580,
(15 April 2020).
https://doi.org/10.1016/j.watres.2020.115580

PATENTS

Materials for membrane distillation applications

Applicant: **University of South Africa, South Africa**

This invention aims to provide a method for producing multi-walled carbon nanotube blended polyvinylidene fluoride (MWCNT/PVDF) membranes for membrane distillation (MD) treatment of saline water. It uses non-solvent induced phase separation (NIPS). The method involves mixing two solvents with different solubility parameters and the use of a dual coagulation bath to control the formation of membrane pore structures and enhance surface hydrophobic properties, so that blended PVDF membranes are produced for application in MD processes.

Patent number: WO/2020/073064
Inventors: E. Mapunda, T. Msagati and B. Mamba
Publication date: 9 April 2020

Process for removing catalyst fines using nanofiltration

Applicant: **Shell Internationale Research Maatschappij BV, The Netherlands**

This invention provides details of a process for removing catalyst fine particles from a hydrocarbon product, using at least one nanofiltration (NF) membrane. The catalyst fine particles measure 0.1 µm or less. The process involves contacting the hydrocarbon product at the feed-side of the NF membrane, recovering a catalyst fines-depleted stream at a permeate side of the membrane, and recovering an enriched stream of catalyst fines at the retentate side of the membrane.

Patent number: WO/2020/069959
Inventors: J.P. Haan, A. Caiazzo and J.L.W.C. den Boestert
Publication date: 9 April 2020

High-temperature alkaline water electrolysis

Applicant: **Giner Inc, USA**

A composite membrane that is suitable for use in a molten alkaline water electrolyser forms the subject of this patent. In one embodiment, the membrane includes a porous support, in the form of a matrix of metal oxide particles randomly arranged to form a plurality of tortuous pores. The composite membrane also includes molten electrolyte, filling the pores of the porous support – the molten electrolyte having hydroxide ion conductivity. The molten electrolyte may be a single species of an alkali hydroxide or an alkaline earth hydroxide. Alternatively, it may be a eutectic or non-eutectic mixture of two or more species of alkali hydroxides or alkaline earth hydroxides. The membrane may further include one or more additives, such as a "coarsening inhibitor", crack attenuator and a reinforcing material. It may be used to make a molten alkaline membrane water electrolyser that is electrically efficient, say the inventors.

Patent number: WO/2020/072553
Inventors: H. Xu, A. Sweet, W. Greene and K. Patil
Publication date: 9 April 2020

Water treatment device based on forward osmosis

Applicant: **Organo Corp, Japan**

The treatment device and method detailed by this patent can be applied at low cost to water that contains at soluble silica and/or a hard component. The device described has a pretreatment system that is equipped with a means of removing soluble silica and the hard component, and a reverse osmosis (RO) membrane-based component, which performs condensation treatment of the pretreated water (obtained from the pretreatment device). A forward osmosis (FO) membrane-based device is used to treat the condensed water obtained from the RO membrane treatment component. The dilution draw solution, which is used in the FO device, is also used in the pretreatment device.

Patent number: WO/2020/071177
Inventors: Y. Nakamura, T. Nakano and K. Takiguchi
Publication date: 9 April 2020

Biocompatible membrane that acts as a "molecular sieve"

Applicant: **The Electrospinning Co Ltd, UK**

This invention makes use of a biocompatible membrane which can act as a size-selective membrane or a "molecular sieve", for controlling the delivery of external substances to particular target cells both *in vitro* and *in vivo*. The membrane contains pores of a suitable size that allow the passage of solute molecules, such as glucose, but prevent the passage of larger particles, for example, cells. The membrane can be packaged together with the target cells of interest, optionally on a scaffold, to provide artificial tissues and organs for use in the treatment of disease. Advantageously, the membrane is able to shield any encapsulated cells from the host's immune system. This invention also relates to a therapeutic composition comprising an inner portion and a biocompatible membrane fully or partially surrounding this inner portion. The membrane comprises at least two layers. The first layer is a porous, non-woven network of thermoplastic polyurethane polymer fibres produced by an electro-spinning process and has a porosity of greater than or equal to 50%; an average pore diameter of less than 5 µm; and a thickness of 10 µm to 250 µm. The second layer also consists of a porous, non-woven network of thermoplastic polymer fibres formed by electro-spinning. The mean average fibre diameter of the second layer is greater than the mean average fibre diameter of the first layer and/or the average pore diameter of the second layer is greater than the average pore diameter of the first layer. This invention also relates to the use of the membrane and therapeutic composition – for instance, encapsulating therapeutic cells.

Patent number: WO/2020/070484
Inventors: R.J. McKean, T.-M. Cirstea and B. Robb
Publication date: 9 April 2020

Thin-film composite membrane and method for making it

Applicant: **The Penn State Research Foundation, USA**

This invention pertains to a thin-film composite (TFC) membrane, incorporating a porous layer of at least one organic polymer that comprises macrocycles. In one embodiment, the TFC membrane comprises a macrocycle selected from the group consisting of: pillar[4]arene, pillar[5]arene, pillar[6]arene, pillar[7]arene, pillar[8]arene, crown ether, calixarenes, porphyrins, cyclodextrins, and combination of these. In another embodiment, the TFC membrane further comprises a polymeric support. In one embodiment the macrocycles in the TFC membrane comprise a pore that has a diameter of 1–10 Å, and thickness of between 1 nm and 1000 nm. In another aspect, this invention also concerns a method of making the TFC membrane. This involves creating a solution containing a first organic species; providing a macrocycle; mixing the solution comprising the organic species and the macrocycle to form a mixture; and forming the TFC membrane. The step of mixing the solution may further involve mixing a second organic species. The step of forming the TFC membrane involves polymerising the mixture. In a further embodiment, the solution described is produced from water and a solvent selected from a group consisting of methanol, ethanol, isopropanol, 1-propanol, n-butanol, sec-butanol, isobutanol, and tert-butanol. In addition, the step of providing the macrocycle further includes providing a support and irradiating it with ultraviolet light in an atmosphere of ozone. The TFC membrane is formed on a support.

Patent number: WO/2020/072594
Inventors: M. Kumar, W. Song, Y.-X. Shen and C. Lang
Publication date: 9 April 2020

Method for inspecting a separation membrane module

Applicant: **Toray Industries Inc, Japan**

This patent provides details of a technique for preparing a water quality profile, and a method for inspecting a separation membrane module and water treatment apparatus. The approach described is based on a series of steps. In the first, the water that is to be treated is supplied to a separation membrane module and permeate is obtained. The module has a supply port for the water being treated and multiple permeate outlets. In the second step, the ratio of the flow-rates of the respective permeates, flowing out of the multiple permeate outlets, is varied. A third step involves measuring the respective water quality of permeate, and in a fourth, the relationship between the ratio of the respective permeate flow-rates varied in the second step and the respective water quality of permeate measured in the third step, are plotted as a scatter diagram. Steps 2 to 4 are repeated multiple times.

Patent number: WO/2020/071507

Inventors: H. Hamada, M. Taniguchi and K. Tomioka

Publication date: 9 April 2020

Coating composition for making a microporous membrane hydrophilic

Applicant: **JNC Corp, Japan**

The purpose of this invention is to produce a microporous membrane that is permanently hydrophilic. The aim is to achieve this without clogging its fine holes. According to the abstract of the associated patent, a way of making a microporous membrane hydrophilic has been discovered without hindering its permeability. This is accomplished by coating the microporous membrane with a cross-linking agent monomer. The patent provides details of a coating composition, which includes a trifunctional acrylate compound, for making the membrane hydrophilic.

Patent number: WO/2020/075712

Inventors: R. Matsumoto, T. Nagasako and T. Iwasaki

Publication date: 9 April 2020

Pore-forming peptides for controlling pore size

Applicant: **Adolphe Merkle Institute, University of Fribourg, Switzerland**

This patent covers pore-forming peptides or proteins modified using DNA nanotechnology, which provide definition and control of pore size, and increase stability when inserted into a lipid membrane. Chemical modifications are easily made to the compound through hybridisation to the oligonucleotide attached to the peptide or protein. The compound can hybridise to a DNA template, thereby defining the number of monomers assembled to a pore and the size of the formed pore. The DNA template can range from a unique single strand – composed of multiple hybridisation sites separated by flexible linkers – to a complex rigid DNA nano-construct, such as a DNA origami-based ring, serving as a scaffold for pore formation. Hydrophilic modification at the transmembrane segment or terminus of the peptide provides long-lived pores and keeps the compound in a membrane-spanning conformation. The compound can be combined with various moieties and hydrophilic modifications on the transmembrane terminus (which is inserted into the lipid membrane during pore formation), with many possible attachment positions being present.

Patent number: WO/2020/074399

Inventors: A. Fennouri, J. List and M. Mayer

Publication date: 16 April 2020

Treatment of whey demineralisation effluents

Applicant: **Synutra France International, France**

In general, this invention relates to the field of treating demineralisation effluents. In particular, it concerns a method for demineralising whey and treating the effluents produced, recycling such effluents and a facility that is suitable and capable of implementing the processes described. The method for treating the whey demineralisation effluents involves applying reverse osmosis (RO) to the effluent that is recovered, in such a way as to obtain permeate and retentate, and neutralising the RO retentate to a pH of between 6 and 9. The neutralised RO retentate is treated by nanofiltration to obtain a NF permeate comprising monovalent ions and a NF retentate containing divalent ions and residual organic matter. In addition, the NF permeate, obtained in the previous step, is treated by bipolar membrane electrodialysis, in such a way as to obtain at least one acid solution and at least one basic solution. According to the associated patent, the method described can be used to treat these effluents, limit their environmental impact and generate solutions that can be used in the whey demineralisation process as such. Advantageously, this also helps to reduce the cost of demineralising wheys because some of the water of the electrodialysis process originates from the treatment of the generated effluents. Furthermore, the method helps to reduce the total quantity of effluent sent to the treatment plant, claims the inventor.

Patent number: WO/2020/074823

Inventor: M. Chaveron

Publication date: 16 April 2020

Efficient separation and enrichment of lithium

Applicant: **Qinghai Institute of Salt Lakes, Chinese Academy of Sciences, China**

A method has been developed for the efficient separation and enrichment of lithium. The process involves pretreatment, by subjecting brine in a salt pan to dilution and filtration in order to obtain pretreated brine. This is then separated using a nanofiltration (NF) separation system to obtain fresh water and concentrated water (with the NF separation system running at an operating pressure of 1.0–5.0 MPa). During the primary concentration stage, the fresh water produced is subject to a first concentration process – using a reverse osmosis (RO) system – in order to obtain a concentrated solution and fresh water. The secondary concentration stage subjects the RO concentrated solution to a second concentration process that uses an electrodialysis system, which produces electrodialysed concentrated water and fresh water. The electrodialysed concentrated water is a solution that is enriched with lithium ions. The method described couples different membrane separation techniques.

Patent number: WO/2020/073610

Inventors: M. Wang, Y. Zhao, Y. Li and H. Wang

Publication date: 16 April 2020

These patent summaries are based on materials from the World Intellectual Property Organization's Patentscope database https://patentscope.wipo.int.

EVENTS CALENDAR

16–18 May 2021
Global Water Summit 2020
Madrid, Spain
Contact: Roxy Ali, Global Water Intelligence, Media Analytics Ltd, Suite C, Kingsmead House, Oxpens Road, Oxford OX1 1XX, UK
Tel: +44 1865 204208
Email: roxy.ali@globalwaterintel.com
www.watermeetsmoney.com

9–11 June 2021
IDA 2021 International Water Reuse and Recycling Conference
Rome, Italy
Contact: International Desalination Association (IDA), PO Box 387, Topsfield, MA 01983, USA
Tel: +1 978 774 0959
https://wrr.idadesal.org

9–12 June 2021
XIII Scientific Conference 'Membranes and Membrane Processes in Environmental Protection'
Zakopane, Poland
Contact: Irena Korus, Silesian University of Technology, Institute of Water and Wastewater Engineering, Konarskiego 18, 44–100 Gliwice, Poland
Tel: +48 32 237 2020, Fax: +48 32 237 1047
Email:irena.korus@polsl.pl
http://mempep2021.systemcoffee.pl

15–17 June 2021
Membrane Technology Forum
Minneapolis, Minnesota, USA
Contact: BNP Media, 2401 W. Big Beaver Road, Suite 700, Troy, MI 48084, USA
Tel: +1 248 362 3700 or +1 844 644 7449
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20–24 June 2021
Singapore International Water Week (SIWW)
Singapore
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Email: info@siww.com.sg
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19–22 July 2021
Membrane Technology Conference & Exposition
West Palm Beach, Florida, USA
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Tel: +1 772 463 0820
Email: custsrv@amtaorg.com
www.amtaorg.com/awwaamta-membrane-technology-conference-exposition

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the company's founder, said: 'This is an important step in the full-scale commercialisation of our TS-30 system.'

'This partnership will enable us to tap world-class German engineered technology and the expertise to demonstrate a low-temperature (60–80°C, or 140–176°F) liquid-waste treatment system that will reduce the energy consumption by up to 90%, compared with conventional liquid-waste incineration methods.'

'This will not only make a new benchmark in energy usage for industrial liquid-waste treatment, but also reduces the carbon footprint by at least ten times, compared with conventional incineration/evaporation methods, whilst recovering every drop of water and valuable resources to close the loop and save the environment.'

Dieter Knoblich, CEO, Piller SEA Pte Ltd, added: 'We are excited to be working with Memsift by providing a cost-effective and energy-efficient liquid-waste treatment system for low mass-flows. Once again we prove that Piller blowers are a key element in thermal separation processes – also and especially in terms of energy and CO_2 reduction.'

Memsift is also exploring further markets for its technologies as reported in a previously published news focus feature article (*Membrane Technology*, October 2020, pages 4–5).

The company recently entered into a MOU with the Connecticut Center for Applied Separations Technologies (CCAST) at the University of Connecticut (UConn) in the USA. It says this agreement will enable it to explore application studies and pilot trials for its technologies in North America.

For further information, visit: www.memsift.com & www.piller.de

DuPont MABR modules are used to upgrade Severn Trent wastewater treatment facility

In the UK, 10 OxyMem membrane aerated biofilm reactor (MABR) modules from DuPont Water Solutions have been installed at Severn Trent's Redditch Spernal site in Worcestershire.

As a result, this central treatment plant has become the largest MABR in the UK, says DuPont.

The facility processes wastewater from the surrounding catchment area and excess biosolids from satellite plants. Consideration for future population growth and tighter ammonia consents led Severn Trent to look for improved process efficiencies. Rather than expanding the plant, the water company opted for an upgrade by converting it to an integrated fixed film activated sludge MABR system.

According to DuPont, its OxyMem MABR modules were simply lowered into the existing anoxic zone on-site, over a two-day period, to boost nitrification capacity of the current process. The technology offers simultaneous chemical oxygen demand (COD) and ammonia removal, with nitrification rates 2–3 times greater than those achievable by using moving bed biofilm reactor technology at the design temperatures.

This full-scale installation follows an extensive pilot trial at Severn Trent's Minworth site on the northeastern outskirts of Birmingham, which lasted 12 months. The OxyMem system proved its value, producing sludge at just 0.13 kg TSS/kg COD applied, compared with the typical 0.3–0.4 kg TSS/kg COD applied for activated sludge. Energy consumption was low and the aeration efficiency was 4.5 kg O_2/kWh – two to three times more efficient than conventional technologies.

Following the pilot and successful installation, Justin Silver, Innovation Project Manager, Severn Trent, said: 'Severn Trent is excited at the potential for MABR technology as a cost-effective way to retrofit and upgrade activated sludge plants to meet tightening effluent standards and to cater for population growth.'

John McConomy, Commercial Director, OxyMem, DuPont, added: 'The modularity of this self-contained solution means not only can it be easily dropped into place, but it is also scalable should needs change.'

Earlier this year, DuPont acquired OxyMem Ltd, which develops and produces MABR systems for the treatment and purification of municipal and industrial wastewater, together with three other companies – inge GmbH, Memcor and Desalitech Ltd (*Membrane Technology*, February 2020, page 1).

For further information, visit: www.dupontwatersolutions.com, www.oxymem.com & www.stwater.co.uk

(A technology focus feature article entitled 'DuPont further expands its portfolio of products that helps to purify, conserve and reuse water' will be published in the December 2020 issue of the newsletter.)