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Membranes Are a Flexible Intensification Solution

Membranes can be used in a diverse array of industries and applications. They are an inherently intensified technology that are typically constructed as small units that can be numbered-up to increase scale. Membranes are an obvious focus area for the RAPID Manufacturing Institute, which is working to further their development and application.

Certain characteristics of membranes make them well-suited to modular chemical process intensification (MCPI):

- Membranes use momentum, rather than thermal energy, as the driving force for separation. In most cases, electric pumps, fans, and compressors deliver momentum, and because electricity requires relatively little infrastructure for distributed generation, membranes are suited to remote and modular applications.
- Membranes can couple unit operations. For example, membrane reactors combine reaction and separation in one system, overcoming equilibrium limitations by continuously removing reaction products.
- Membrane development has taken advantage of advances in materials science to create thin and robust membranes. New materials, such as metal organic frameworks (MOFs), can be combined with polymer systems to produce composite membranes with unique separations capabilities. New fabrication techniques, such as additive manufacturing, enable production of very thin, scaffold-supported membranes that are free of defects.

These promising characteristics have motivated the RAPID manufacturing institute to sponsor projects and initiatives that apply membranes to water cleanup, hydrocarbon separation, and membrane reactors.

Water cleanup

Robust membranes for black liquor concentration. A team at Georgia Institute of Technology is developing graphene oxide (GO) membranes to concentrate black liquor, a byproduct of the Kraft pulping process. The team is working to ensure that the membranes can be produced at a low cost and maintain stability and long service life in highly corrosive, high-pH streams. Their ultimate goal is to reduce the thermal load of multiple-effect evaporators to dramatically reduce energy consumption.

Modular mechanical vapor compression membrane distillation (MVC-MD) to treat produced water. Researchers at Texas Tech Univ. are working to integrate mechanical vapor compression with membrane distillation (MVC-MD) to intensify the treatment of water from hydraulic fracturing. Integrating membrane distillation greatly reduces the energy intensity of the combined separation operation.

On-demand treatment of wastewater using 3D-printed membranes. To address challenges associated with membrane manufacturing, a team at the Univ. of Pittsburgh is 3D-printing membranes to separate a multicomponent and multiphase water-oil mixture.

Hydrocarbon separation

Energy-efficient separation of olefins and paraffins. Compact Membrane Systems (CMS) is using a fluoropolymer membrane to separate olefins and paraffins. The CMS technology has a long life and resists poisoning. The technology is designed to recover propylene from propane in a polymerization reactor purge stream; the propylene is then recovered and recycled to the reactor.

Advanced nanocomposite membranes for natural gas purification. This project at the Univ. of Texas at Austin focuses on preparing and characterizing novel nanocomposite membranes. These new membranes are composed of MOF materials and nanoparticles that have outstanding separation properties, particularly for removing acid gases (*e.g.,* CO_2) from natural gas. If successful, these membrane systems will be smaller than existing technologies that process comparable amounts of gas and will emit less hydrocarbons, increasing energy efficiency and reducing emissions.

Membrane reactors

Para-xylene selective membrane reactor. A Univ. of Minnesota team is focusing on the production and purification of para-xylene, one of the main feedstocks for the polymer industry. The project integrates a para-xylene ultraselective zeolite membrane with an isomerization catalyst in a membrane reactor. The aim is to increase the yield of para-xylene beyond the limits of chemical equilibrium by selectively removing para-xylene from the reactor as it is produced. The goal of this approach is to increase productivity, as well as reduce separation energy, capital intensity, and greenhouse gas emissions.

Thermoneutral propane dehydrogenation via a solid-oxide membrane reactor. A Univ. of Michigan project focuses on the production of propylene from propane using perovskite solid-oxide membrane reactors. This technology can be applied to both centralized and distributed operations. In distributed operations, the technology could use shale natural gas liquids as feedstock. Perovskite solid-oxide membranes can simultaneously conduct oxygen and hydrogen ions. This could enable a highly selective thermo-neutral process that operates at lower temperatures and drives chemical equilibrium conversion forward, while minimizing additional reactions that produce unselective combustion products. CEP