Queen Mary Chemical Engineers Have Developed Technologies to Slash Energy Consumption in Industry

2022-10-02

In two papers published in the journals Nature and Science, Queen Mary's Professor Livingston and Dr Zhiwei Jiang present their work on nanomembranes – exquisitely thin membranes that can provide an energy efficient alternative to current industry practices.

They demonstrate their technology can be used to refine crude oil and cannabidiol (CBD) oil – two industry giants. Around 80 million barrels of crude oil are processed every day to create fuel and plastic, in a process which consumes massive amounts of energy. The cannabidiol oil industry is fast growing - the Global Cannabidiol (CBD) Market is estimated to reach USD 47.22 Billion by 2028, up from USD 4.9 Billion in 2021.

Andrew Livingston, Professor of Chemical Engineering at Queen Mary, said: 'A vast amount of energy is consumed in industry separating molecules. The aim of our research is to provide low energy alternatives to these processes. Due to the innovations in the chemistry we used to make these membranes, we can achieve molecular architectures that achieve exquisite separations, and provide less resource intensive techniques for the separation of molecules.'

Dr Zhiwei Jiang, Research Associate at Queen Mary, said: 'Thinner is better - the liquid passes through the membranes much more quickly, rapidly speeding up the process, and therefore reducing the plant footprint while processing same quantity of liquids.’

Hydrophobic polyamide nanofilms for refining crude oil into fuel and plastic

Hydrocarbons extracted from crude oil are the main ingredients for manufacturing fossil fuels, plastics, and polymers. The process by which they are extracted is extremely energy intensive.

Most refineries process crude oil using atmospheric and vacuum distillation, in which crude oil is heated to separate compounds according to their boiling points. Typical refineries process 100,000-250,000 barrels/day – there are some processing over 1 million. The maximum temperature for the distillation varies based on the quality of the crude, but the distillation temperatures can exceed 500 °C. This process consumes 1100 terawatt-hours per year – nearly 1% of global energy use.

Membrane technology that can separate the molecules in crude oil by their different sizes and classes could be a far more energy efficient process, consuming 90% less energy than distillation columns. Exceptionally thin nanomembranes have proved successful for extracting fresh water from sea water by rejecting the salt while allowing the water to permeate through reverse osmosis (RO) process. The researchers sought to separate hydrocarbons from crude oil by a parallel method.

This requires nanomembranes to be hydrophobic (water repellent), which can provide high affinity and rapid pathways for processing hydrocarbons. However, conventional nanomembranes used for RO are hydrophilic (having affinity for water) in nature and exhibit limited permeance of hydrocarbon liquids, remaining too low for industrial crude separation.

Professor Livingston's team used multiblock oligomer amines to create hydrophobic polyamide nanofilms that provide100 times faster permeance than that of hydrophilic nanofilms. By reducing the membrane thickness to approximately 10 nanometers, they achieved permeance one order of magnitude higher than the current state-of-the-art hydrophobic membranes, with a comparable selectivity in fractionation of real crude oil. As a result, the membranes developed by the team could markedly reduce the energy consumption of processing crude oil. The analysis of the fractionation was performed by ExxonMobil in a laboratory in the United States.

Polymer nanomembranes for enriching cannabidiol (CBD) oil

Conventional chemical and pharmaceutical industries use 45-55% of their total energy consumption during production in molecular separations. In a paper in Nature, Professor

Livingston's team, including researchers at Northwestern University in Evanston (USA), and Bielefeld University (D), present polymer nanomembranes with aligned supramolecular macrocycles. These exhibit superb and extremely selective filtration properties that exceed the conventional polymer nanomembranes currently used across the chemical and pharmaceutical industries. Conventional polymer nanomembanes have broad distribution of the pore size that lacks a controllable way to be precisely tuned.

In this new breed of polymer nanomembranes, the molecularly predefined macrocycles are aligned to provide sub-nanometer pores as a highly effective filtration gateway that separates molecules with a size difference as low as 0.2 nm. The researchers show that the arrangement, orientation and alignment of these small cavities could be realized by selectively functionalized macrocycle molecules.

As a functional proof of concept, these nanomembranes are applied to high-value pharmaceutical separations for enriching cannabidiol (CBD) oil, exhibiting higher ethanol permeance and molecular selectivity than commercial state-of-the-art membranes. This novel concept offers feasible strategies to orientate porous materials into nanopores in membranes that can provide accurate, fast and energy-efficient molecular separations.

Read the original article on Queen Mary University of London.