MOF Membranes Promise Energy Savings

Researchers say technique is inexpensive to scale up.

By Chemical Processing Staff

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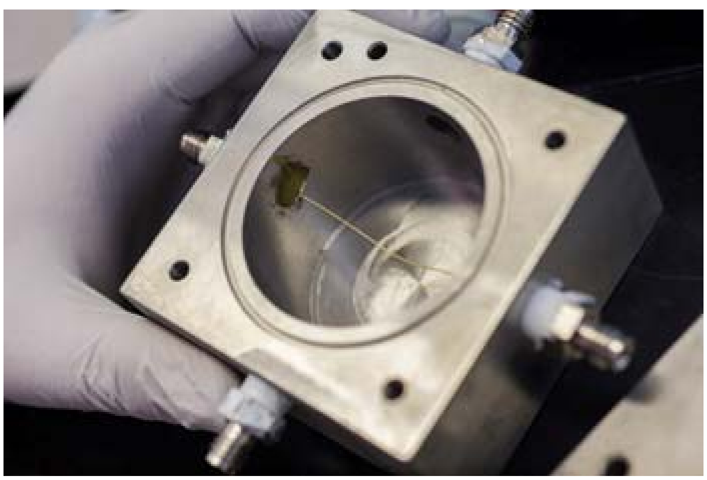
A new class of metal-organic framework (MOF) membranes fabricated inside hollow polymer fibers could potentially change large-scale, energy-intensive chemical separations, say researchers at Georgia Institute of Technology (Georgia Tech), Atlanta.



MOF PROTOTYPE

Figure 1. This photograph shows the inside of the prototype hollow-fiber metal-organic framework (MOF) membrane module, revealing a hollow fiber MOF membrane mounted in it. *Source: Rob Felt, Georgia Tech.*

The membranes produced with the technique can separate hydrogen from hydrocarbon mixtures, and propylene from propane, and if scaled up, could cut the cost of gaseous and liquid separations, reduce energy consumption and produce less carbon dioxide, they add.

“This work opens up new ways of fabricating molecular sieving separation membranes using microscopic hollow fibers as a platform,” says Sankar Nair, a professor in the School of Chemical & Biomolecular Engineering at Georgia Tech. “Many of the separations that currently are done with energy-intensive techniques could one day be performed with membranes fabricated by a scaled-up version of our methodology.”

In contrast to traditional energy-intensive separation processes such as distillation or cryogenic techniques, molecular sieving membranes use semipermeable materials to separate molecules from mixtures that are produced by chemical reactions or found in raw material feedstocks.

A pressure gradient drives the process, and the membranes are designed to pass certain molecules through their pore structures.

To produce the MOF membranes, larger numbers of hollow fibers spun from inexpensive polymers deliver a large surface area. A 1-m3 hollow-fiber member module could provide as much as 10,000 m^2 of membrane area.

A microfluidic technique brings the different reactants needed to form MOF membranes into contact inside the fibers. The fibers’ inner diameter is typically 100 microns or less. This limits the amount of reactants and changes the physical and chemical forces that control membrane formation.

The researchers then adjusted the flow and positioning of the reactants and their solvents to control the location of the MOF membrane films, allowing their formation on the inside, outside or within the structure of the fibers.

The technique enabled the researchers to create membrane films made of the MOF ZIF-8 inside three fibers simultaneously. A recent issue of the journal Science highlights more details.

“We have combined a high-performance MOF material with a new fabrication technique to come up with a membrane that can be scaled up in an inexpensive way,” Nair explains. “A key realization behind this development is that if you want to scale up MOF membrane growth using hollow fiber modules, you have to first learn how to scale down their growth in the microscopic environments of individual hollow fibers.”

Several challenges exist going forward. “From a technological perspective, the process would have to be successfully scaled up to longer fibers (ideally up to 50 cm in length) and for many fibers at a time. These efforts would be more efficient if fundamental work was also conducted on understanding in more detail the relationships between the processing conditions and the resulting structure and function of the membranes,” says Nair.

To scale up the membranes to sizes suitable for industrial separations, “we will have to optimize the process so that we can prepare defect-free membranes over much longer lengths (up to 10×) than presently reported, and using many more fibers (say a hundred) in parallel. This will create a viable bench-scale demonstration of scale-up in our opinion.”

While a pilot-plant scale-up is probably several years away, Nair notes that bench-scale demonstration of scale-up is a more near-term goal.

Susceptibility to clogging could be an issue. The researchers have tested the ZIF-8 membranes over periods greater than 1 month, and Nair notes the membranes appear stable and robust. However, he points out that, as with all commercial membrane processes, “a front-end filtration unit will be required to prevent undesirable particulates from entering the hollow fibers."

"Our immediate next goals will be to focus on other hydrocarbon gas separations encountered in refineries and petrochemical plants," he adds. The researchers also plan to investigate tuning the membrane formation by changing the MOF or the polymer hollow fiber material itself.

Phillips 66 has been collaborating with the researchers on the project since 2008. "At the moment, we are continuing our collaboration for further evaluation and development of the technology," concludes Nair.

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