A strategy to fabricate metal-organic framework membranes for the separation of hydrocarbons

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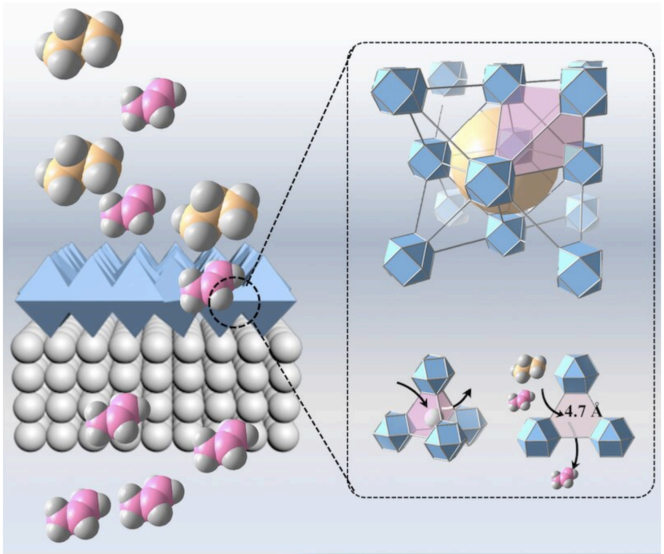

Schematic membrane-based separation process (left) and structure demonstration of the Zr-fum-fcu-MOF membrane (right). Credit: Zhou et al.

The separation of light hydrocarbon mixtures is among the most important petrochemical and industrial processes. This process is currently regarded as highly energy intensive, as it has so far been carried out using conventional techniques, such as cryogenic distillation.

An alternative way of separating light hydrocarbons could be to use membrane-based separation processes. In contrast with cryogenic distillation and other traditional processes, membrane-based separation is not driven by heat, thus it could help to reduce the overall energy requirements of light hydrocarbon separation. Over the past few years, scientists worldwide have thus been trying to develop and identify new materials that could be used to fabricate membranes to carry out such energy-intensive separations.

Researchers at King Abdullah University of Science and Technology (KAUST) have recently introduced a versatile electrochemical directed-assembly strategy to fabricate membranes for the separation of hydrocarbons. This strategy, introduced in a paper published in *Nature Energy*, allowed them to fabricate metal-organic framework as continuous thin films and deploy them as membranes that could reduce the energy input in hydrocarbon separation processes by almost 90% compared to conventional single distillation processes.

"Our previous explorations on the design, discovery and development of metal-organic frameworks (MOFs) have unveiled a new platform based on the face-cantered cubic (fcu) MOFs, which turned out to be amendable to ultra- fine tuning of their pore-apertures, positioning the fcu-MOFs as suitable sorbents for various key separations," Mohamed Eddaoudi, one of the researchers who carried out the study, told TechXplore. "The main objective of our study was to take them to the next level and process these selected adsorbent materials into practical membranes that offer high permselectivity at industrially relevant high pressures and under aggressive conditions. In addition to that they can be easy to manufacture in a scalable and robust fashion."

Fabricating defect-free polycrystalline MOF membranes is very challenging, as it requires a highly controllable growth process. To fabricate their membranes, Eddaoudi and his colleagues used an electrochemical approach that works by applying a controlled external current to promote the crystallization and intergrowth of polycrystalline fcu-MOF thin film on a porous support.

"Compared with the conventional solvothermal growth, this electrochemical approach is highly controllable, so high-quality thin films can be obtained," Sheng Zhou (Ph.D. student and first author) explained. "Also, the fabrication conditions are much milder and faster than using other methods, requiring only room temperature, atmospheric pressure and short growth time (two hours). As a result, this strategy is more practical and scale-up friendly."

By successfully combining reticular chemistry with an electrochemical synthetic approach, Eddaoudi and his colleagues were able to fabricate continuous, defect-free fcu-MOF membranes with stable, intrinsic molecular sieving properties. These properties make the membranes they created particularly promising for the separation of light hydrocarbons.

In addition, the researchers were the first to develop a methodology that can be used to determine the right conditions for fabricating closed thin-film membranes based on a series of MOFs with various types of linkers. In the future, membranes created using the strategy they developed could significantly enhance hydrocarbon separation processes.

"The deployment of our Zr-fum-fcu-MOF membranes in a hybrid membrane–distillation system offers the potential to decrease the energy input by nearly 90% compared to a conventional single distillation process for propylene/propane separation," Dr. Osama Shekhah (senior research scientist) said. "We are currently trying to expand our membrane design and fabrication to other systems, to address more challenging yet important separations. At the same time, we are working on various path to scale-up the fabrication of our membranes, including preparing large-scale hollow fiber membranes." Eddaoudi said.

More information: Sheng Zhou et al, Electrochemical synthesis of continuous metal–organic framework membranes for separation of hydrocarbons, *Nature Energy* (2021). DOI: 10.1038/s41560-021-00881-y

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