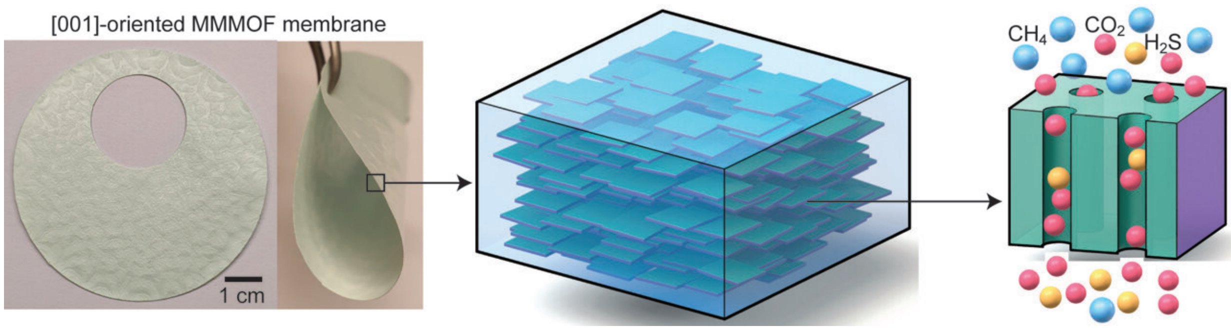
Designing the perfect membrane for clean separation of gases

June 2 2022



Oriented mixed-matrix metal-organic framework membrane effectively removes hydrogen sulfide and carbon dioxide from natural gas in an energy-efficient manner. Credit: 2022, KAUST

Selective removal of detrimental gases, e.g., hydrogen sulfide (H_2S) and carbon dioxide (CO_2) from natural gas (CH_4) could become simpler and highly effective using a new class of oriented mixed-matrix metal-organic framework (MMMOF) membrane developed at KAUST that may enable better use of this cleaner fossil fuel.

The advantages of membrane technology over traditional separation (e.g., cryogenic distillation and adsorptive separation) are that it is energy-efficient and simpler to operate. Mixed-matrix membranes (MMMs) formed by embedded selective adsorbent in a continuous polymer matrix represent an appealing combination of the adsorbents and easy processing of polymers.

"Our achievement, in-plane alignment of MOF nanosheets inside the polymer matrix and successful translation of adsorbent distinct separation properties into a processable matrix is revolutionary," says Shuvo Datta.

MOFs are hybrid organic-inorganic materials that contain metal ions or clusters held in place by organic molecules known as linkers. Varying these parts allows researchers to create a suitable pore-aperture that permits selective sorption and/or diffusion of one gas over another based on their size.

"These crystalline materials are difficult to process into a defect-free oriented continuous membrane, but we developed a simple solution casting method to process them," says Mohamed Eddaoudi.

Conventional MMMs often undergo nanoparticle-polymer interface incompatibility, and channels or pores of adsorbents are randomly oriented that hamper the gas separation. To avoid those limitations, MMMOF membranes were conceived and constructed based on three interlocked criteria: (i) a fluorinated MOF (KAUST-8), as a molecular sieve adsorbent that selectively enhances H_2S and CO_2 diffusion while excluding CH_4; (ii) tailoring MOF crystal morphology into nanosheets with maximally exposed 1D channel and promoting a nanosheet-polymer interaction; and (iii) in-plane alignment of nanosheets in polymer matrix and attainment of the uniformly oriented MMMOF membrane.

The MMMOF membrane demonstrated far better H_2S and CO_2 separation from natural gas under practical working conditions (e.g., high pressure, high temperature, prolonged time of 30 days, etc.) compared to conventional MMMs.

"In fact, this centimeter-scale flexible oriented membrane can be regarded as a single piece of a flexible crystal in which thousands of MOF nanosheets are uniformly aligned in a predefined crystallographic direction and the gaps between aligned nanosheets are filled with polymer. It's the first of its kind," says Shuvo Datta.

"I have no doubt that this discovery will inspire scientists in academia and industry to explore various practical membranes to address numerous industrial energy-intensive separations," says Mohamed Eddaoudi.

The study is published in *Science*, and the team now wants to scale up their procedure to demonstrate its commercial potential. They will also seek to apply it to other important industrial gas separation processes.

More information: Shuvo Jit Datta et al, Rational design of mixed-matrix metal-organic framework membranes for molecular separations, *Science* (2022). DOI: 10.1126/science.abe0192. www.science.org/doi/10.1126/science.abe0192

Provided by King Abdullah University of Science and Technology