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Mixed matrix formulations with MOF molecular sieving for key energy-intensive separations

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Membrane-based separations can improve energy efficiency and reduce the environmental impacts associated with traditional approaches. Nevertheless, many challenges must be overcome to design membranes that can replace conventional gas separation processes. Here, we report on the incorporation of engineered submicron-sized metal-organic framework (MOF) crystals into polymers to form hybrid materials that successfully translate (face-centered cubic) **fcu**-MOF's excellent molecular sieving properties into the resultant membranes. We demonstrate, simultaneously, exceptionally enhanced separation performance in hybrid membranes for two challenging and economically-important applications: both CO_2 and H_2S removal from natural gas and butane isomer separation. Notably, the membrane molecular sieving properties demonstrate the deliberately regulated and contracted MOF pore-aperture size can discriminate between molecular pairs (Figure 1). The improved performance results from the precise control of the linkers delimiting the triangular window, which is the sole entrance to the **fcu**-MOF pore. This rational-design hybrid approach provides a general toolbox for enhancing transport properties of advanced membranes bearing molecular sieve fillers with sub-nanometer sized pore-apertures.

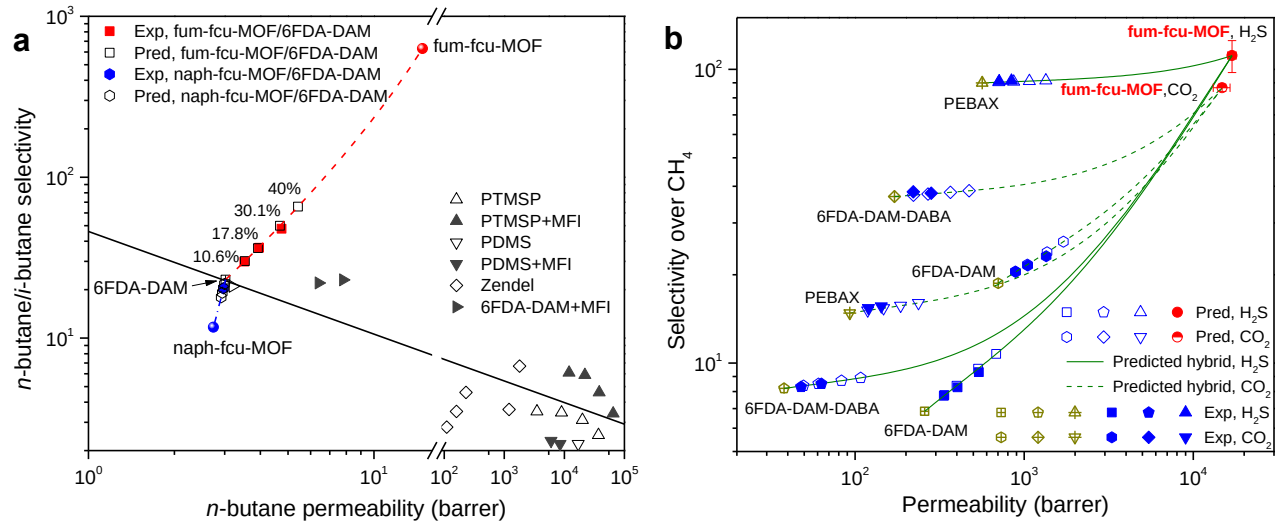


Figure 1. Gas permeation results. a, nC_4 permeability and nC_4/iC_4 selectivity of Y-*fum*-**fcu**-MOF and Eu-*naph*-**fcu**-MOF incorporated 6FDA-DAM hybrid membranes with various MOF loading by wt%. Pure gas permeations were conducted under 1.72 bar at 75 °C. Other reported polymeric and hybrid membranes are compared. The eye-guiding line (black) is only used to indicate a general "trade-off" between permeability and selectivity in reported polymer-based membranes. **b**, CO_2 and H_2S permeability, CO_2/CH_4 and H_2S/CH_4 selectivity of Y-*fum*-**fcu**-MOF/polymer hybrid membranes with various MOF loading by wt% (from left to right, 6FDA-DAM: 10.6, 17.8, 30.1, 40; 6FDA-DAM-DABA: 9.9, 17.7, 20, 30, 40; PEBAX: 10.1, 20.0, 30, 40). To gain individual permeabilities in model natural gas permeation (20/20/60 $H_2S/CO_2/CH_4$ mixtures with total pressure of 6.9 bar), pure H_2S or CO_2 permeation was conducted under 1.38 bar, and pure CH_4 permeation was conducted under 4.14 bar at 35 °C. Permeation properties of the pure Y-*fum*-**fcu**-MOFs and Y-*fum*-**fcu**-MOF/polymer hybrid membranes are predicted by using the measured permeability and selectivity of the 6FDA-DAM membranes and Y-*fum*-**fcu**-MOF/6FDA-DAM hybrid membranes according to the theoretical model for mixed-matrix hybrid membranes. 1 barrer = 10^{-10} cc(STP) cm cm^{-2} s^{-1} $cmHg^{-1}$.