

Highly gas-permeable semi-rubbery semi-ceramic composite materials for efficient CO₂ separation membranes

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(foreign research visit 7-11 August 2017)

Molecular separations by the aid of membranes have a potential to revolutionize global energy consumption leading to better global economy and environment [1]. Large scale carbon dioxide (CO₂) separation and capture is among the most important processes to realize carbon-neutral society in the nearest future. Membrane separation is most promising approach for the economically feasible CO₂ capture. Major problem of the membrane-based CO₂ separation is low fluxes, that are not sufficient to treat huge amount of CO₂ emitted industrially. Membranes suitable for post combustion CO₂ capture need to have permeances as high as several thousands GPU (*gas permeances unit*, GPU = 7.5 · 10⁻¹² m³(STP)/m²·s·Pa) the values achieved by only few state-of-art membranes [2]. This became possible by utilization of composite (multilayer structure) membranes containing three main layers: nano-thick selective layer, gutter layer and porous support (Fig.1a). Gutter layer ensures proper adhesion between layers, fills the defects and provides mechanical stability. Layered architecture of composite membranes helps to overcome the roadblock of low permselectivity and high gas-permeable materials are needed to further improve their performance.

In my main research I investigate the formation of the metal oxide (TiO₂, ZrO₂, *ceramic compound*) crosslinked polydimethylsiloxane (PDMS, *rubbery polymer*) using the in-situ sol-gel of alkoxides with silanol terminated PDMS (schematically given in Fig. 1c). Physical properties of such hybrids are strongly influenced by two factors – content of the metal oxide and molecular weight of precursor PDMS-OH. In particular, the designed materials demonstrate superior gas separation performance compared to conventional PDMS i.e. both selectivity and permeability are increasing (Fig. 1b). Such behavior suggests the formation of the nanosize molecular sieving fillers [3] within the PDMS matrix (Fig. 1c) that improve the separation performance proportional to differences in gases kinetic diameters.

Results of short foreign research visit to University of Texas in Austin and experiments conducted in the laboratory of Prof. Benny Freeman will be also reported.

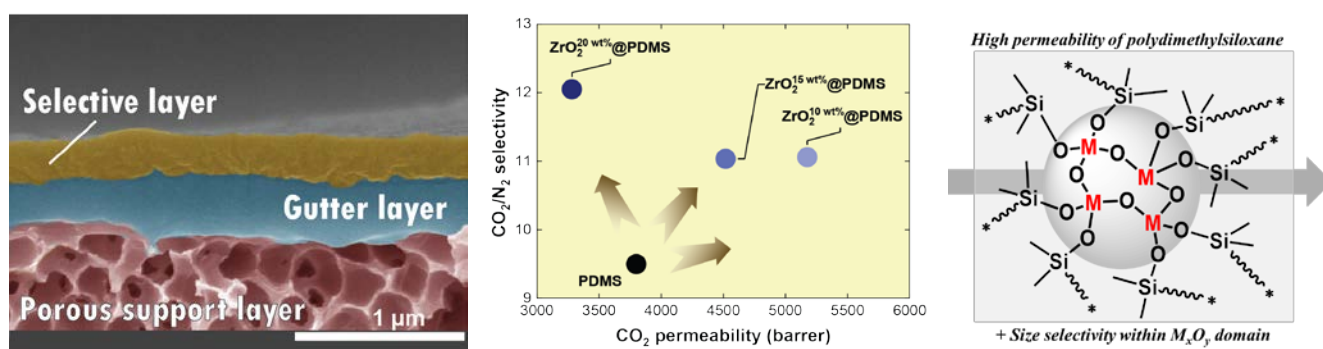


Figure 1. a) Tri-layer composite membrane structure; b) CO₂/N₂ separation performance of ZrO₂/PDMS hybrids compared to conventional PDMS; c) Mechanism of M_xO_y/PDMS hybrid materials gas transport driven by high permeability of PDMS improved by size-sieving within the M_xO_y domains.

References

- 1) Sholl D.S. & Lively R.P. *Nature*, 2016, **532**, 435–437.
- 2) Merkel T. C. et.al, *J. Memb. Sci.*, 2013, **359**, 126–139.
- 3) Park H.B. et.al. *Science*, 2017, **356**, 1–10.