17th International Conference on Inorganic Membranes
New Frontiers for Inorganic Membranes
July 1 - 5, 2024
Oceania Convention Center - Florianópolis - Brasil

DEVELOPMENT OF MEMBRANES BASED ON PDMS/POLYURETHANE FOR CO_2/N_2 SEPARATION

B. N. S. Sabrina[a*], L. R. Camila[b] and M. A. S. Alysson[b]

[a] Institute of Chemistry, University of Brasília, Brasília, Brazil
[b] Department of Mechanical Engineering, University of Brasília, Brasília, Brazil
[*] sbrnsammour@gmail.com

Membranes based on polydimethylsiloxane (PDMS) and polyurethane (PU) have been the subject of studies for the preparation of membranes for the separation of the CO_2/N_2 gas mixture, primarily found in combustion gases [1-3]. PDMS is a polymer belonging to the silicone elastomer group, falling into the class of organic/inorganic hybrid polymers characterized by the repetition of the siloxane (Si-O) bond in its structure, as depicted in Fig. 1(a). On the other hand, polyurethanes are a versatile class of materials characterized by the R-NH-CO-O-R' linkage, where the urethane/urea group forms a hard segment, and the polyester/polyether group forms the soft segments, as represented in Fig. 1(b). The combination of PDMS with polyurethane has attracted attention due to advantages such as improved thermal stability, high flexibility at low temperatures, and mechanical resistance [4-8]. Given the promising results of membranes based on PDMS and polyurethanes, this work aims to produce this material without the use of solvents or incorporation syntheses.

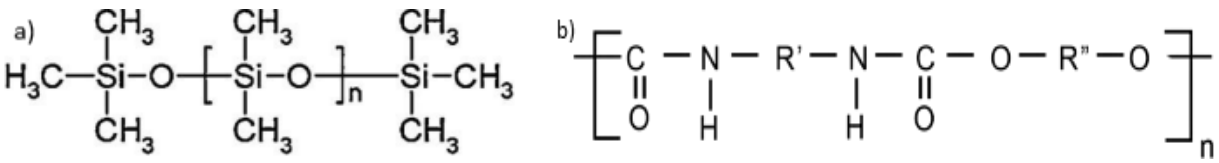

Fig. 1- Structural formula of (a) Polydimethylsiloxane [9] and (b) Polyurethane [10]

The membranes were fabricated using PDMS in a ratio of 10:1 w/w (base: curing agent), acquired from Sigma-Aldrich under the trade name Sylgard® 184, and polyurethane in a ratio of 1:1 w/w (diisocyanate: polyol), obtained from Avipol. Membrane production and performance optimization involved testing different polymer concentrations and thermal treatments.

For membrane characterization, Fourier-transform infrared spectroscopy (FTIR) technique were employed. The obtained signals revealed distinctive features of both polymers, such as peaks at 1256 cm^{-1} (Si-CH_3 bond), 1054 cm^{-1} (Si-O-Si), and 786 cm^{-1} (Si-$(CH_3)_2$), indicative of PDMS [11, 12]. Conversely, bands at 1523 cm^{-1} (N-H bending vibration), 1704 cm^{-1} (ester C=O stretching), and 914 cm^{-1} (symmetric N-CO-O stretching) are associated with polyurethane [13]. Scanning Electron Microscopy (SEM) was adopted to investigate the overall aspects of the surface regions of the membranes, both those composed of PDMS and polyurethane and the pure membranes. Fig. 2(a) and 2(c) highlight that the PDMS and PDMS:Polyurethane membranes are dense and homogeneous, while the polyurethane membrane, as shown in Fig. 2(b), exhibits irregularities on its surface.

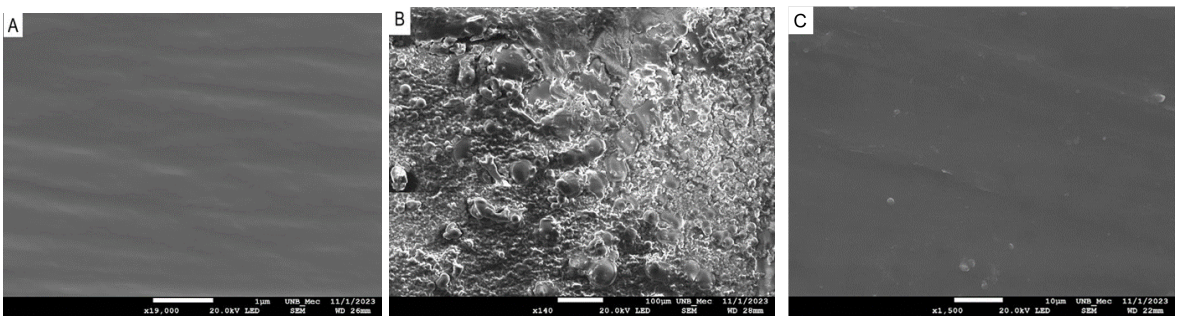

Fig. 2 - SEM micrographs of the (a) PDMS (b) Polyurethane and (c) PDMS:PU (85:15 w/w) membranes

Permeation tests were conducted using CO_2 and N_2 to assess the efficiency of the membranes. In Table 1, the permeability and selectivity results for the CO_2/N_2 gas mixture obtained by the produced membranes are observed, demonstrating effectiveness in gas separation with increased selectivity in the manufactured membranes of PDMS:PU.

Table 1- Permeability and Selectivity Results

	PERMEABILITY (mol m^{-1} s^{-1} Pa^{-1} or Barrer)		SELECTIVITY
MEMBRANE	CO_2	N_2	CO_2/N_2
PDMS	1053	448	2,4
PDMS:PU (95:5 w/w)	1356	296	4,6
PDMS:PU (90:10 w/w)	1130	231	4,9
PDMS:PU (85:15 w/w)	1451	256	5,7

[1] Chawla, M *et al*, "Membranes for CO_2 /CH_4 and CO_2/N_2 Gas Separation," Chemical Engineering & Technology, 43, 184-199 (2019).

[2] Chen, Y *et al*, "Amine-containing polymer/zeolite Y composite membranes for CO2/N2 separation," Journal of Membrane Science, 497, 21-28 (2016).

[3] Zhao, S *et al*, "Status and progress of membrane contactors in post-combustion carbon capture: A state-of-the-art review of new developments," Journal of Membrane Science, 511, 180–206 (2016).

[4] Wolf, M. P., G. B. Salieb-Beugelaar and P. Hunziker, "PDMS with designer functionalities - Properties, modifications strategies, and applications," Progress in Polymer Science, 83, 97–134 (2018).

[5] Madhavan, K and B. S. R. Reddy, "Poly(dimethylsiloxane-urethane) membranes: Effect of hard segment in urethane on gas transport properties," Journal of Membrane Science, 283, 357–365 (2006).

[6] Talakesh, M. M *et al*, "Gas separation properties of poly(ethylene glycol)/poly(tetramethylene glycol) based polyurethane membranes," Journal of Membrane Science, 415–416, 469–477 (2012).

[7] Park, H. B., C. K. Kim and Y. M. Lee, "Gas separation properties of polysiloxane/polyether mixed soft segment urethane urea membranes," Journal of Membrane Science, 204, 257–269 (2002).

[8] Jiang, X. (Cindy), J. Ding and A. Kumar, "Polyurethane–poly(vinylidene fluoride) (PU– PVDF) thin film composite membranes for gas separation," Journal of Membrane Science, 323, 371–378 (2008).

[9] Seethapathy, S and T. Górecki, "Applications of polydimethylsiloxane in analytical chemistry: A review," Analytica Chimica Acta, 750, 48–62 (2012).

[10] Hong, T *et al*, "Polyurethane-based gas separation membranes: A review and perspectives," Separation and Purification Technology, 301, 122067 (2022).

[11] Liu, J., S. Wu, M. Zou, X. Zheng and Z. Cai, "Surface modification of silica and its compounding with polydimethylsiloxane matrix: interaction of modified silica filler with PDMS," Iranian Polymer Journal, 21, 583–589 (2012).

[12] Bodas, D and C. Khan-Malek, "Formation of more stable hydrophilic surfaces of PDMS by plasma and chemical treatments," Microelectronic Engineering, 83, 1277–1279 (2006).

[13] Jiao, L., H. Xiao, Q. Wang and J. Sun, "Thermal degradation characteristics of rigid polyurethane foam and the volatile products analysis with TG-FTIR-MS," Polymer Degradation and Stability, 98, 2687–2696 (2013).