NEW MEMBRANE BASED HYBRID UNIT OPERATION FOR GAS SEPARATION

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A lab-scale test has been completed for the implementation of a new membrane based separation process for gaseous streams, described in an application for patent recently submitted by the University of Bologna and CNR [MISE 102015000037715]. The new process can be run on the same modules currently used for conventional membrane based gas separations and it counts on the periodic swing of downstream pressure while upstream conditions are kept constant. The entire process is managed without switching streams and allowing for constant flow rate and composition of both feed and retentate, while permeate is collected from the module at assigned frequency, resulting in an overall on-average steady state process. Time based on-off control of permeate collection ultimately produces alternate sorption/desorption steps in the membrane, associated to increase/decrease cycles of downstream pressure in the process, similarly to what occurs in pressure swing adsorption (PSA) processes. Indeed, consistently with the hybrid nature of the new process, the specific dynamic control of downstream pressure allows to take advantage of both resistive (permeation) and capacitive (sorption) properties of the membrane, as well as associated characteristics for selectivity. By changing the duration of pressure swing period in the new process, from very low to very high values, the resistive or capacitive properties of the membrane can be distinctively stimulated to explore different balances between key component recovery and separation factor in the process. In order to prove the above concept, with reference to the problem of post-combustion carbon capture a two-layer membrane has been prepared in which a dense polydimethylsiloxane (PDMS) coating was applied to the external surface of a tubular porous ceramic membrane according to 1:50 ratio between thicknesses of polymeric and ceramic layer. Polymer and ceramic layers confer desired resistive and capacitive properties, respectively, to the membrane, which is ultimately endowed with relatively high permeance to carbon dioxide, as well as sorption capacity. In fact, characteristic times for sorption and permeation phenomena in the membrane are considerably different and interesting results for effective membrane performances in CO_2/N_2 separation may be obtained through the dynamic control of the process when period Tp fot the imposed pressure swing cycle is increased from negligible to significant fraction of characteristic time Ts for the sorption process in the membrane. Effective permeance Π_E and selectivity α_E measured in the lab-scale test for the organic-inorganic membrane prepared in this work, for the case dilute atmospheric CO_2/N_2 mixture at room temperature was used as feed stream, are reported in table below as function of pressure swing frequency. Experimental results are expressed as ratio between effective performances in dynamic regime and corresponding value for steady state processes (permeance Π_0 and selectivity α_0) and table relates the latter to the ratio between pressure swing period and characteristic time for sorption. The results clearly show the potential of the new process and its additional flexibility with respect to traditional membrane based gas separation, as rather different performances for permeate to selectivity ratio can be established by properly setting the pressure swing period, for the case of assigned loading and fixed characteristics of the membrane module.

Results for effective membrane permeance and separation factor in dynamically controlled gas separation process

Tp/Ts	0.021	0.042	0.083	0.17	0.33	0.5	1.2
Π_E/Π_0	0.96	0.91	0.86	0.68	0.47	0.36	0.15
α_E/α_0	1.1	1.6	2.9	4.5	6.4	6.9	7.3