Tailoring the CO2 Permeability and Selectivity of Organic Membranes from the Ground-Up

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Abstract

Controllable molecular transport through polymeric membranes constitutes an important consideration in the design of functional soft materials intended to remove undesirable component species from gas or liquid mixtures. Of particular interest here are membranes capable of selectively separating gases such as CO_2, an acid gas and combustion diluent largely responsible for global climate change, from other commercially relevant gases (e.g., N_2, O_2, H_2, or CH_4). While gas separation routinely relies on the use of glassy polymers (with relatively low intrinsic free volume) to sieve gases on the basis of molecular size, alternative approaches combine glassy polymer matrices with (non)porous nanoscale additives to achieve desired performance through the use of mixed matrix membranes (MMMs). Since permeation in the limit of Fickian diffusion is generally described by a solution-diffusion mechanism, gas permeation that is not limited by molecular transport (diffusivity) can likewise be controlled by thermodynamic means (solubility). Such membranes are referred to as "reverse-selective" since they can promote the permeation of larger molecules relative to smaller molecules due to chemical affinity with the polymer membrane. Examples of solubility-driven gas-separation membranes are discussed here with specific regard to CO_2 removal. Although most commercial membrane modules employ homopolymers or polymer blends, we likewise explore the possibility of using nanostructured polymers, such as block copolymers, for the purpose of controlling molecular transport during filtration. This consideration leads to the under-investigated use of polymer "mesoblends" and block ionomers. By combining the physical properties associated with diffusion through heterogeneous media and the chemical properties afforded by targeted synthesis/modification, next-generation polymer filtration membranes exhibiting high CO_2 permeabilities and selectivities can yield new design paradigms for functional materials with superior properties from the ground-up.

Biography of Presenting Author

Richard J. Spontak was a research scientist with Procter & Gamble before he joined the NCSU faculty in 1992. Spontak has over 104 publications in peer-reviewed journals, and his work has been featured on the cover of Microsc. Res. Tech. and Langmuir. Spontak conducts studies to improve the current understanding of microstructural polymer systems, which are of scientific interest as self-assembling polymers and commercial value as adhesives, (bio)compatibilizing agents, nanotemplates, and membranes. His group's efforts are at the cutting edge of block copolymer research: e.g., they have

obtained the first 3D images of the bicontinuous gyroid (Ia3d) and sponge (L3) morphologies. They characterize polymers with electronspectroscopic microscopy, and dispersions/gels with freeze-fracture replication and cryo-TEM techniques. Use of these tools has expedited the study of block copolymers and their blends/gels, and has helped to elucidate novel polymer gelation mechanisms, PDLC composition/morphology relationships, and interpolymer complexation. Other areas of interest include polymer alloying through mechanical attrition, transmission electron microtemography, and modification of polymer solutions via salting-in.

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