

82e Nanoparticle Filled Rubbery Polymer Membranes for CO₂ Sequestration

Scott T. Matteucci, Haiqing Lin, Benny Freeman, Victor Kusuma, Miquel Jose-Yacaman, Sumod Kalakkunnath, and Douglass S. Kalika

Traditionally, the addition of impermeable particles to rubbery polymeric membranes reduces light gas and vapor permeability as particle loading increases. This phenomenon is well known for barrier materials, and there are numerous models, such as the one derived by Maxwell, that accurately predict the permeability loss of membranes filled with impermeable particles.[1]

Recently, nonporous metal oxide nanoparticles (primary particle diameter as low as 2.5 nm) have been dispersed in rubbery polymer to make membranes that have over an order of magnitude higher light gas (i.e., CO₂, N₂, O₂, H₂) permeability with little or no change in selectivity relative to the neat polymer, which runs counter to traditional filled rubbery polymers. For example, the CO₂ permeability was 1100 barrers in filled 1,2-butadiene as compared to 52 barrers for the unfilled polymer. For both materials, the CO₂/N₂ selectivity was 14, at 35 oC and 3.4 atm. Nanoparticle filled poly(ethylene oxide) membranes reached permeabilities as high as 1700 barrer while maintaining a CO₂/N₂ selectivity of 25, at 35 oC and 3.4 atm. The degree of permeability enhancement is particle loading dependent, with maximum particle loading over 50 weight percent for some materials. Nanocomposites have been prepared with different polymer matrices (e.g., polar, non-polar, and crosslinked rubbery polymers) and different particle surface chemistries (e.g., MgO, SiO₂, TiO₂, etc.). These materials have been characterized using light gas sorption and permeation to monitor gas transport properties as well as SEM and TEM to characterize particle distribution within the polymer matrix.

Furthermore, nanocomposites with rubbery matrices often exhibit significantly improved gas transport behavior at low temperatures. Both light gas permeability and selectivity increases substantially with decreasing temperature. However, in some of these materials the gas transport enhancements are limited by the onset of nanoparticle-induced polymer crystallization, as characterized by permeation and DSC experiments.

[1] R. M. Barrer, J. A. Barrie and M. G. Rogers, Heterogenous Membranes: Diffusion in Filled Rubber, *Journal of Polymer Science, Part A: Polymer Chemistry*, 1 (1963) 2565-2586.