Proceedings of the 7th International Conference on Energy Harvesting, Storage, and Transfer (EHST'23)
Canada – June 07-09, 2023
Paper No. 117
DOI: 10.11159/ehst23.117

Free Standing Mixed Matrix Membranes for Carbon Capture

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Extended Abstract

Climate change due to greenhouse gas (GHG) emissions has catastrophic effects on global ecosystems and communities. The mitigation of climate change can be achieved by using renewable energy sources and by capturing carbon dioxide (CO2), the major GHG accounting for 76% of total emissions [1-3]. Therefore, it is essential for the sustainability of the planet to develop CO2-capturing technology and utilize it in productive ways, such as in enhanced oil recovery, the manufacture of fuels, building materials, and storage in underground geologic formations. Polymeric membranes have been researched for carbon capture and sequestration (CCS) for many years. The main obstacle that must be overcome before employing industrial sized CCS membranes is the development of stable, high surface area, high-performance, porous materials for this process. Furthermore, synthesizing free standing membranes without support is a challenging task. This extended abstract focuses on the synthesis of free-standing polymeric membranes with nanofillers, for which the performance is characterized by their selectivities and permeabilities towards CO2, N2 and CH4. The goal is the produce mechanically stable, high-performance, free standing mixed matrix membranes for CCS.

Since methyl cellulose (MC) is found to be a good encapsulation material [4] and renewable polymer, it has been used as a mechanically strong matrix to form the polymeric base of the membranes. Polyvinyl alcohol (PVA) is also incorporated with MC for half of the trials, to test its effect on the performance. The MC or MC/PVA matrix was impregnated with both fixed and mobile carriers to improve CO2 permeance and selectivity: polyallylamine hydrochloride (PAA) was added as an amine carrier, as it has been shown to increase CO2 permeability by increasing its facilitated transport [5]; either zeolite 13-X, kaolin (Kln) or Zn(2-methylimidazolate) (ZIF-8) was added as an adsorbent filler. Six hybrid, free standing mixed matrix membranes were synthesized using the layer-by-layer deposition method: MC/PAA/ZIF-8, MC/PVA/PAA/ZIF-8, MC/PAA/13-X, MC/PVA/PAA/13-X, MC/PAA/Kln, and MC/PVA/PAA/Kln. Their performances were analyzed by testing permeabilities and selectivities, using a lab-scale single-gas permeation setup. This was performed by passing a single gas flow of N2, CO2 or CH4 through the membrane and measuring the permeate and retentate flow rates using bubble flowmeters.

MC/PVA/PAA/ZIF-8 was found to have a selectivity of 2.01 for CO_2/CH_4. MC/PAA/13-X/PVA had a relatively high CO_2/N_2 selectivity of 1.4 among the membranes prepared. The MC/PAA/ZIF-8/PVA membrane shows the highest permeability of N_2, CO_2 and CH_4 among all membranes. The results show that PVA addition improves the selectivity of the membranes. The MC/PVA composite with a PAA amine carrier and a ZIF-8 filler yielded the most promising CCS membrane of this study in terms of permeability and selectivity. It is evident that MC successfully acts as a matrix to hold all components; furthermore, PAA, ZIF-8, and 13-X improve the selectivity of gases, as expected.

References

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