Innovative Process for the Purification of Green Aviation Fuel Additive "Dimethoxymethane": Pervaporation

Derya Unlu

Nomenclature

DMM	Dimethoxymethane
FTIR	Fourier transform infrared spectroscopy
PEI	Polyetherimide
SEM	Scanning electron microscopy

1 Introduction

Dimethoxymethane is a liquid, 100% miscible in diesel fuel, does not comprise C–C atomic bonds, and contains 42% oxygen by weight. The decrement of the cetane number compared to traditional diesel fuels results in a delay in the ignition time. This situation allows more air to be drawn into the fuel jet and reduce the output of particulate matter (Song & Litzinger, 2006; Marrodán et al., 2016).

Dimethoxymethane is produced by the reaction of formaldehyde or paraformaldehyde with methanol. After the synthesis reaction, dimethoxymethane is obtained as a mixture of methanol. The methylal and methanol form an azeotrope mixture with 94.06 wt% methylal. Therefore, conventional distillation methods are not appropriate for the separation of these binary and ternary mixtures. Pervaporation, reactive distillation, and extractive distillation processes have been used in the literature to separate the methylal/methanol mixtures (Dong et al., 2018; Wang

D. Unlu (✉)
Faculty of Engineering and Natural Sciences, Chemical Engineering Department, Bursa Technical University, Bursa, Türkiye
e-mail: derya.unlu@btu.edu.tr

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et al., 2012; Xia, 2012). In this study, pervaporation is used in the separation of dimethoxymethane/methanol mixtures. The optimum operation parameters were investigated.

2 Materials and Methods

2.1 Materials

PEI was acquired from Sigma Aldrich. N-methyl-2-pyrrolidone was obtained from Carlo Erba.

2.2 Membrane Preparation

Different concentrations of PEI were dissolved in N-methyl-2-pyrrolidone at 90 °C. When the polymer was completely dissolved, the resultant polymer solution was poured into glass petri dishes and dried in an oven at 120 °C for 5 h.

2.3 Membrane Characterization

The synthesized membranes were characterized by SEM, FTIR, and TGA.

The chemical bond structure of PEI membrane was analyzed using FTIR. The morphologies of the membrane was analyzed by using a scanning electron microscope. The thermal stability of PEI membranes was acquired using a Mettler Toledo thermal analyzer.

2.4 Sorption Capacity of Membrane

The sorption capacity test was performed in room temperature to investigate the interaction of methanol and dimethoxymethane with the membrane. The membranes were cut into small pieces and weighed on a precision balance to measure dry mass. The membranes were put in petri dishes containing methanol and dimethoxymethane. At certain time intervals, the membranes were dried with filter paper and reweighed in precision balance. This operation was continued until the mass of the membranes was stabilized. The sorption capacity of the membranes was calculated by determining the affinity of membrane.

2.5 *Purification of Dimethoxymethane by Pervaporation*

The purification of dimethoxymethane was performed in a laboratory-scale pervaporation unit. Effects of polymer concentration on membrane, feed methanol concentration, and operation temperature on separation performance were investigated. The operation temperature was controlled by using an oven. Membrane chamber was placed in an oven. While the upstream of the membrane was under atmospheric pressure, the downstream of the membrane was held below 1 mbar. The membrane area was 9.61 cm^2. Pervaporation tests were carried out for 4 h. The flux (J) and selectivity (α) were calculated to specify the purification success of the membrane.

3 Results and Discussion

3.1 *FTIR Analysis of PEI Membrane*

Figure 1 shows the FTIR spectrum of PEI membrane. The characteristic absorption bands of PEI membranes can be observed at 2960 and 2850 cm^{-1} (C-H), 1716 and 1650 cm^{-1} (C=O), 1364 cm^{-1} (C-N) and 1234 cm^{-1} (C-O-C), and 1050 cm^{-1} (C-O). The presence of imide groups (O=C-N-C=O) in the membrane structure can be seen in two bonds at 1716 and 1364 cm^{-1}, respectively (Manshad et al., 2016; Santos et al., 2019).

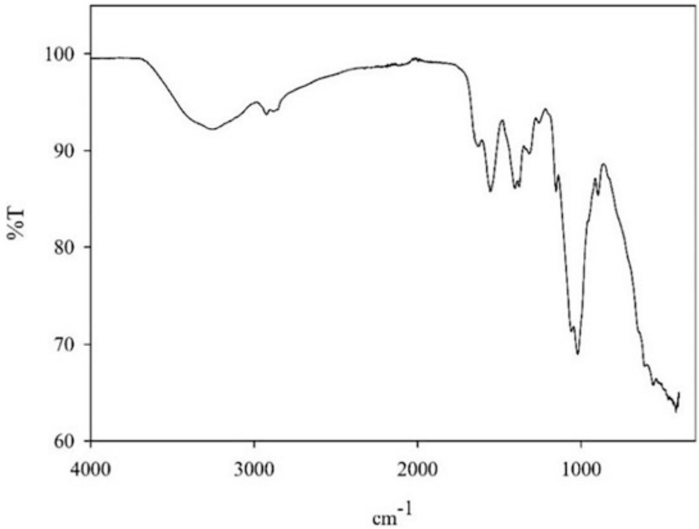

Fig. 1 FTIR spectrum of PEI membrane

Table 1 Effect of the PEI concentration on the sorption capacity of PEI membrane

Polymer concentration (wt.%)	Sorption capacity of different components (%)	
	Methanol	Dimethoxymethane
10	15	0
15	38	0
20	52	0

3.2 Sorption Capacity of PEI Membrane

Table 1 shows the effect of the PEI concentration on the sorption capacity of PEI membrane.

PEI concentration in membrane has an important effect on the sorption feature of membrane. As the PEI concentration increases, sorption capacity of membrane increases. This is related to interaction between the methanol and the functional groups of the polymer.

3.3 Pervaporation of Dimethoxymethane

Pervaporative purification performance of PEI membrane for dimethoxymethane/methanol mixture is investigated in different operation conditions. PEI membrane shows infinite selectivity. This means that PEI membrane shows an excellent separation performance.

4 Conclusion

In this research, dimethoxymethane, which is used as a fuel additive, was purified by using a PEI membrane. Dimethoxymethane/methanol mixture was separated successfully. The synthesized blend membranes were characterized by different analysis methods. The PEI membrane shows a good sorption capacity for methanol and superior separation performance in pervaporation tests. In pervaporation tests, the effects of PEI concentration, operation temperature, and feed concentration on separation performance were investigated. The results obtained are consistent with the high affinity of the membrane for methanol, so PEI membrane is appropriate for the purification of dimethoxymethane.

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