547g Microchannel Based Liquid Separation Utilizing Pervaporation Process

Sudhir Ramprasad and James D. Palmer

The increasing pressure of the global economy necessitates investigation of avenues that offer potential competitive advantages. The utilization of microchannels in chemical processes has resulted in the process intensification of heat exchangers [1-2], reactors [3-5], etc. due to reductions in transport distances. Microscale membrane separation involving gases have been widely reported in literature but liquid phase chemical separation for a chemical microsystem is in a less advanced stage. S.M.Lai et al have developed a membrane microreactor consisting of 35 channels of 300 µm in width and 600µm in depth for the synthesis of fine chemicals. Their work highlights the increase in yield due to improved mass transfer rates at the microscale [6].

The main objective of our research is to evaluate the process intensification effects in a liquid phase microscale separator. Liquid phase separations are the focus due to the lower diffusivities of a liquid when compared to a gas. Typical values of liquid and gas phase diffusivities are 10-1 cm2/s and 10-5 cm2/s respectively. Using Fick's law of diffusion, one predicts that 0.4 s is required for a liquid to diffuse 20 µm and 63 s to diffuse 250 µm. Similarly, a gas would only require 4e-5 and 6.3E-3 s over the same respective distances. Therefore, liquid separations should benefit from smaller diffusion distances as the predicted timescales are of a similar order of magnitude as contact times of the liquid in the separator.

The pervaporation process is a membrane based separation process utilized in this research. In pervaporation, the components of a liquid selectively diffuse through a membrane and are subsequently vaporized due to the low pressure exerted on the permeate side of the membrane. In this project, experiments involving separation of ethanol/water by pervaporization in a microchannel device will be discussed. Ethanol/water system was chosen as a model system due the available literature of pervaporation performance [7]. The ability of the membrane to separate this binary mixture was characterized by experimentally measuring the permeate flux and separation factor.

The microchannels in the microseparator were fabricated by dry etch process at Louisiana Tech University. Microchannel depths of 20 to 250 µm are being studied. The feed ethanol solution was fed through microchannels parallel to the direction of the commercially available polymeric dehydration membrane. An elevated inlet feed temperature and vacuum at the permeate region creates the driving force required for efficient separation. Changes in the feed concentration that occurred during the experiment as a result of selective removal of water by the membrane were measured at regular intervals using a refractometer. The mass change in the feed was acquired at 20 second intervals for the entire duration of the experiment. The total flux and selectivity as a function of microchannel depth and flow-rates will be reported.

Keywords: Chemical Microsytem, Microchannels, Process Intensification, Pervaporation

References:

[1]. Schubert. K., Bier.W, Brandner. J., Fichtner.M, Franz.C, Linder.G; "Realization and testing of microstructure reactors, micro heat exchangers and micromixers for industrial applications in chemical engineering", in Ehrfeld.W, Rinard. I.H., Wegeng. R.S. (Eds.) Process Miniaturization: 2nd International Conference on Microreaction Technology, IMRET 2; Topical Conference Preprints, pp. 88-95, AIChE New Orleans, USA (1998).

[2]. Ehrfeld.W, Hessel. V., Haverkamp.V , "Microreactors", Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH, Weinheim, (1999).

[3]. Mazanec. T., Perry. S., Tonkovich. L., Wang.Y, “Microchannel gas-to-liquids conversion-thinking big by thinking small” Studies in Surface Science and Catalysis, 169-174, (2004)

[4]. Lowe.H, Hessel.V, and Mueller.A, “Microreactors. Prospects already achieved and possible misuse”, Pure Applied Chemistry.,Vol.74,No.12,2271-2276, (2002)

[5]. Wegeng RS, MK Drost, and DL Brenchley , "Process Intensification Through Miniaturization or Micro Thermal and Chemical Systems in the 21st Century." 3rd International Conference on Microreaction Technology, Frankfurt, Germany. February (1999).

[6]. Lai.S.M, Ng. C.P., M-Aranda. R., Yeung. K.L., “Knoevenagel condensation reaction in zeolite membrane microreactor”, Microporous and Mesoporous, 66, 239-252, (2003)

[7]. Huang. R.Y.M. “Pervaporation Membrane Separation Process”. Elsevier Science Publishers B.V., Amsterdam, (1991).