Gas Permeation and Separation in ZSM-5 Micromembrane Unit

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The last few years have seen increasing interest on microchemical systems including micromixers microreactors and microseparators. The smart, integrated microchemical systems are expected to bring into realization a distributed, on site and on demand production network for high value added products in the form of miniature factories and micro-pharmacies. Such microchemical devices will enable the rapid implementation of new synthesis and process technologies for more efficient production under environmentally responsible and safe conditions. It has been acknowledged that microscale separation is one of the core technologies that needed to be developed for microchemical system. Most separation processes can benefit directly from the large surface area-to-volume ratio that can be obtained in a microseparator. In fact, extraction and membrane separation have been successfully miniaturized. It is expected that membrane will play an important role in microscale separation.

Zeolites and molecular sieves are ideal materials for micromembranes. Zeolites are capable of separating molecules by their size, shape and polarity. Close boiling compounds, isomers and azeotropes were successfully separated using zeolite membranes. The crystalline zeolites also have excellent mechanical strength and thermal stability, and are resistant to most acids, bases and organic solvents. This work describe the successfully fabrication of freestanding zeolite micromembranes on silicon substrate. The procedure involves pre-fabrication of support structure, followed by selective seeding and growth of oriented zeolite films. Low temperature template removal using ozone avoids the crack and defect formations associated with high temperature treatment methods. The zeolite micromembranes were tested for single gas permeation using permanent gases and hydrocarbon vapors. Excellent permselectivity with evidence of molecular sieving was observed from the experiments. The thickness and composition (i.e., Si/Al ratio) of ZSM-5 affects both the permeation and permselective of the membrane for the various gases. Binary (i.e., C_3/N_2, C_4/N_2), ternary ($H_2/CH_4/CO_2$) and quaternary ($H_2/CH_4/CO_2/CO$) separation experiments were also conducted to demonstrate that the zeolite micromembranes are efficient separator.