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Application of etched aluminum flow-through membrane as catalyst support

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ABSTRACT

We have developed novel catalyst supports using aluminum etched with microchannels as microreactors. The novel catalyst support contains ~1–3.5 μm microchannels (~10,000–15,000 microchannels/mm^2) formed on the metal aluminum foil substrate by etching. Flow was through an applied porous membrane. The aim was to provide a reaction space with short controlled residence time and high catalytic activity. We confirmed whether reactions occur in the 1.7 μm membrane microchannels and evaluated the performance of this membrane compared with alumina granular. Methanol steam-reforming activity of the catalytic membrane shows it is an effective catalyst. Comparison with a crushed catalytic membrane shows that the reaction occurs in membrane microchannels. We deduce that there is no diffusive resistance at all temperatures because the membrane microchannel diffusive length is short compared with granular-type reactor channels.

Introduction

Process innovation is essential to ensure future chemical industries achieve greater effectiveness, higher productivity and a competitive advantage. There has been a growing interest in the use of microreactors to achieve this goal. Microreactors are known to have important advantages over conventional reactor types [1], including significantly large surface-to-volume ratio of microreactor and heat transfer coefficients. It is expected that high rate of heat transfer, high efficiency mixing, short residence time distribution and short diffusive length are achieved in the microchannels. In consequence, microreactors allow accurate control of chemical reaction leading to high efficiency and selectivity. Catalysts are important in chemical reactions in material production, and methods are required to deposit catalysts on structured surfaces and practical structured materials for microreactor.

Microreactors are devices used for chemical reaction and substance production using microspatial phenomena. The International Conferences on MicroReaction Technology (IMRET) is a scientific conference series in the micro process engineering and the sciences of microreactors fields that started in Frankfurt am Main, Germany in February 1997. Since then, thirteen IMRET conferences have been organized by various well recognized societies and institutes, research and development flourished, and many examples of production process have been reported. Micro-fabrication technology is used to manufacture reactor microchannels.

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As far as we know, few reports exist on applied examples of microreactors for gas-phase reactions using solid catalysts [2]. It is a significant challenge to fabricate materials with microchannels of few μm cost-effectively, and catalyst deposition on microchannels remains a major challenge. The development of practical materials and methods to deposit catalysts on structured materials is demanded frequently [3].

We addressed the development of novel catalyst supports having penetration microchannels using wet-etched aluminum with microreactor. The novel catalyst support contains ~1–3.5 μm microchannels (~10,000–15,000 microchannels/mm^2) formed on the metal aluminum foil substrate by etching. The novel catalytic membrane can use the microchannels as reaction channels, can be fabricated easily with low cost and can be mass-produced continuously. This novel catalytic membrane support opens up new possibilities for practical industrial materials.

The motivation for applying the flow-through catalytic etched aluminum membrane reactor is to reach complete conversion in minimum time or space, to take advantage of the high catalytic efficiency, or to reach maximum selectivity for a given reaction because of the narrow contact time distribution. If the catalyst is placed inside the membrane microchannels and the reactants flow convectively through the microchannels, the resulting intensive contact between reactants and catalyst results in a high catalytic activity.

A number of laboratories have studied several materials and reaction systems that apply flow-through catalyst membrane reactors (FTCMRs) [3]. In catalytic membrane reactors, the characteristic dimensions are even smaller than in general microreactors, which results in excellent heat transfer between the fluid and membrane. Catalytic microchannels that penetrate another surface directly result in excellent heat and mass transfer in microchannels. This mechanism contrasts with other membrane reactor concepts that use permselective membranes, and the selectivity in a FTCMR cannot exceed those of an ideal plug flow reactor without diffusion limitations [4,5].

The mean microchannels size of the applied membranes varies. The choice of appropriate microchannels size always represents a tradeoff between intensive contact and a low pressure drop. For gas-phase reactions in microchannel structures below the micrometer scale, improved understanding of flow processes and microeffects in Knudsen and transition regimes is required.

Nevertheless, the reactor concept requires more or less sophisticated catalytic preparation methods, frequently suffers from limited membrane stability and competes with other novel concepts such as microreactors or monolithic reactors. In summary, although several encouraging results have been reported, breakthroughs in FTCMRs are still to be expected.

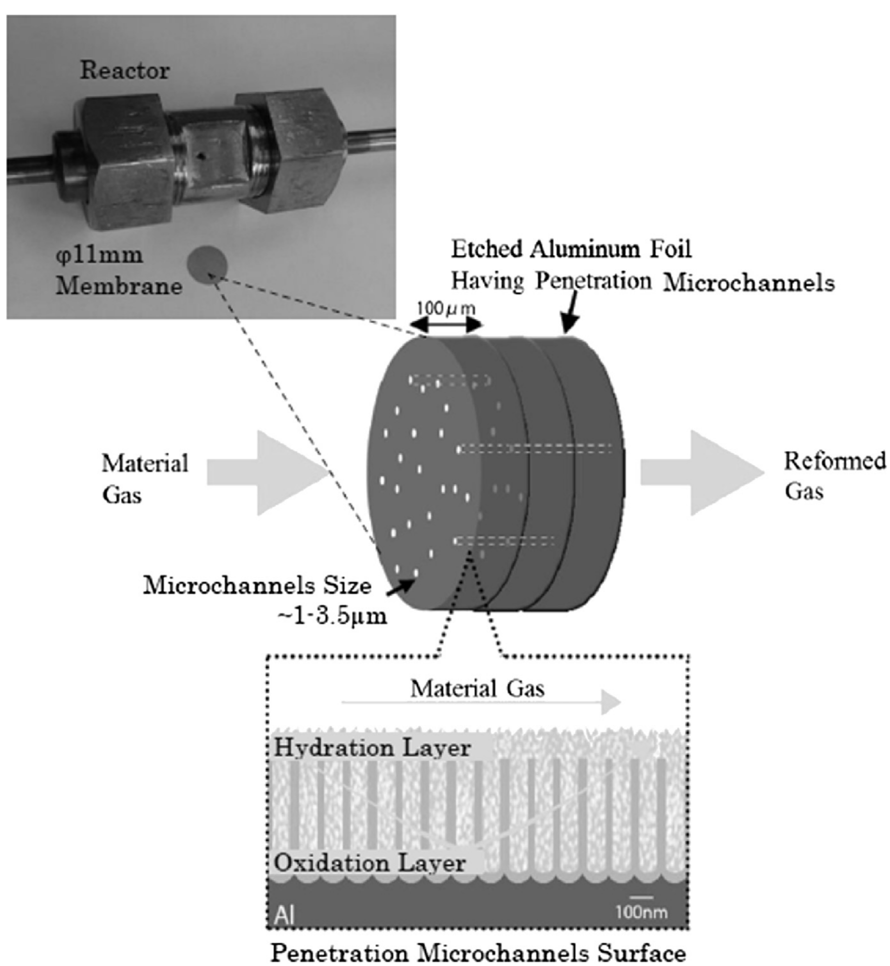

Fig. 1 – Schematic and photograph of membrane and reactor.