Development of catalytic microchannel reactor technology for hydrogen-based gas processing

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Investigations were undertaken involving the development of micro channel reactors for the generation and storage of hydrogen to contribute to the global research concerning the utilization of hydrogen (CCU). The processes considered in this presentation consists of the decomposition of hydrogen-rich chemicals, such as ammonia and formic acid and the methanation involving hydrogen and carbon dioxide. The development and evaluation of catalytic micro channel reactors consisting of laboratory-scale experimentation together with CFD modelling was undertaken to provide a better understanding and information suitable for design purposes. Hydrogen production consisting of ammonia reforming is considered as an attractive operation for fuel cell applications. Ammonia in the liquid state has a hydrogen density of 108.5 kg m-3 at 20°C and 8.57 bara, and allows easy transportation. The endothermic nature of the reforming reaction however makes it dependant on a constant heat source. Thermal coupling between chemical reactions is well known and is an effective process to convey heat. In this investigation ammonia was used as the combustion fuel for the heat generation. A catalytic plate reactor employing micro channels was specially designed to enhance heat transfer and consequently improving the thermal coupling effect. Catalytic plates with micro channels engraved on both sides of each plate were used with catalysts deposited in the micro channels consisting of with 8.5 wt.% Ru/Al2O3 and 5 wt.% Pt/Al2O3 for reforming and combustion, respectively. An experimental evaluation of the microchannel reactor was done to identify suitable operating conditions and it was found that an ammonia conversion of 99.8 % and a hydrogen equivalent fuel cell power output of 0.71 kWe was possible. Formic acid has received increasing attention as a potential hydrogen carrier with a concentration of 4.4 wt% hydrogen and a volumetric capacity of 53.4g/l which surpasses that of most storage devices. Moreover, formic acid is a liquid at standard conditions and relatively non-toxic which makes it easy to transport. It decomposes in the presence of supported gold (Au), silver (Ag) and platinum group metals (PMGs) catalysts to release hydrogen. This investigation involved the development a micro channel reactor with known Au/Al2O3 catalysts consisting of laboratory scale experimental and reactor modelling. The channels of the micro channel reactor were coated with the catalyst and the performance was experimentally evaluated and modelled at temperatures in the range of 150-350 ºC. It was found that hydrogen and carbon dioxide (CO2) were the major products with very low yields of carbon dioxide with conversion of formic acid as high as 98 to 99%, very close to equilibrium. The methanation reaction producing methane was considered as a promising option to implement power-to gas technology with various applications in the transport and industrial sectors. This investigation consisted of the evaluation a microchannel reactor with a commercial 8.5 wt.% Ru/Al2O3 catalyst at different temperatures (250-400°C) and pressures (atmospheric, 5 bar and 10 bar). The microchannel reactor performed best at high temperature and high pressure conditions with a carbon dioxide conversion of 96.8 at 375°C and 10 bar.