Development of Solid Oxide Fuel Cell Systems for Utilization of Ammonia as Energy Carrier

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Among various hydrogen carries, ammonia is one of the promising candidates because of its high hydrogen density and boiling point and ease in liquefaction and transportation. The reaction temperature of ammonia cracking to nitrogen and hydrogen, being about 600˚C or higher, is close to the operating temperature of solid oxide fuel cells (SOFCs). A demonstration of the stack-level ammonia-fueled SOFC systems is an important step for the actual utilization of ammonia-fueled SOFCs. In this study, 200 W class and 1 kW class SOFC stacks were applied for ammonia fueled generation systems.

Catalysts for decomposition of ammonia has been developed. The activity of Ni/Y_2O_3 and SrO modified Ni/Y_2O_3 for ammonia cracking was sufficiently high for combination with SOFCs.

A catalyst based on Co-Ce-Zr composite oxide has been developed for autothermal ammonia cracking. Autothermal cracking of ammonia is characterized by fast start-up in the exothermic condition. The start-up time required from the initiation of electrical heating to the achievement of the steady state was 130 s.

Ammonia fueled SOFC stack systems were evaluated. The cell consisted of a Ni/ZrO_2-based fuel electrode, ZrO_2-based electrolyte, and perovskite-type oxide air electrode. The stack composed of 10 single cells was evaluated from its I–V and I–P characteristics at 770ºC. Four fuel supply systems were connected to the stack, i.e., 1) direct supply of dry ammonia, 2) the ammonia cracker, 3) the autothermal ammonia cracker, 4) The mixture of hydrogen and nitrogen with a composition of 3 to 1 for comparison. For the direct ammonia fueled stack, the supplied ammonia was almost completely decomposed into hydrogen and nitrogen over the anode. The electrical power achieved with this 10-cell stack was about 250 W. The performances for the SOFC stack was comparable for four fuel supply systems.

The stack consisting of 30 single cells was tested at *ca.* 750ºC. Since the performance of the cells has been improved, the power per cell in this stack has also been improved as compared with the cells used in the 10-cell stack. The power of 1073 W can be achieved with the supply of dry ammonia at the current of 50 A which was almost the same as the supply of $3H_2+N_2$ mixture at the same current. The average cell voltage at this operation point was 0.715 V. The DC efficiency was 52.3% at the fuel utilization of 80%. The 1 kW class stack was successfully operated for 1000 h. The 1kW-class stack was also operated by supplying the reacted gas from autothermal ammonia decomposition reactor.

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