§5. Investigation of Hydrogen Isotope Combustion Processes in Atmospheric Pressure Plasma

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Recovery of tritium in a nuclear fusion reactor building is an important concern. Current tritium removal systems remove tritium from a gas by cracking the tritium containing components on a heated precious metal catalyst. The tritium combines with oxygen in the air stream to form tritiated water. Then, the tritiated water contained in the air stream is removed by a molecular sieve bed. Although this system offers adequate efficiency, problems such as a high-pressure drop, the use of a large amount of precious metals, and inefficient heating occur when the processing throughput is quite large. To resolve these problems, we have proposed hydrogen isotope combustion in atmospheric pressure plasma[1]. In the plasma, hydrogen and oxygen radicals are easily generated by high-energy electron and ion impacts in the plasma. These radicals are considered to play an important role in hydrogen oxidation in gas phase reactions. Therefore, it is expected that highly effective oxidation without precious metals can be developed using atmospheric pressure plasma.

We experimentally investigated hydrogen combustion by atmospheric pressure plasma generated by a 2.45 GHz microwave discharge. Small amounts of hydrogen and oxygen were mixed in the operational argon gas during discharge. In this study, the flow rates of argon, oxygen, and hydrogen were set to obtain a total flow rate of 2.7 l/min. The concentrations of hydrogen and oxygen were as high as 1.5 vol% and 14.8 vol%, respectively. A quadrupole mass spectrometer (QMS) was used primarily to measure time evolution of hydrogen, oxygen, and argon gases. To clarify the details of combustion, visible light emissions from the plasma were also observed by a spectrometer through a biconvex lens and an optical fiber.

The degree of hydrogen oxidation, the so-called conversion rate X_h, increased with input microwave power. The maximum hydrogen conversion rate was greater than 80% under these experimental conditions. The X_h tends to saturate with increasing input microwave power. The saturation is attributed to the properties of the plasma source because plasma density also saturates with discharge power. During discharge, an optical emission peak due to OH radicals was observed. As shown in Fig. 1, hydrogen oxidation rate depends strongly on OH radical emission intensity. OH emission intensity could be used as an indicator of the X_h.

Because hydrogen oxidation is a heating process, gas temperature in the reaction chamber is expected to increase with X_h. Gas temperature, which was measured by a thermocouple located 50 mm downstream from the plasma exit. Although X_h increases with discharge power, gas temperatures change slightly with the hydrogen flow rate as shown in Fig. 2. Even in the absence of hydrogen, gas temperature became approximately equal to the temperature during discharge with hydrogen. Because gas temperature without plasma is equivalent to room temperature, this result indicates that the increase in gas temperature is mainly due to argon discharge and not oxidation. Although most of the hydrogen is believed to oxidize in the plasma source, the heated gas might already have been cooled at the measured position.

To clarify the details of the characteristics of combustion, additional spectroscopic measurements and investigation of the plasma parameters are required. Furthermore, the effect of gas temperature on X_h should be investigated.

1) Akahane, K., Ezumi, N. et al.: Fusion Sci. Technol. **60** (2011) 1343.

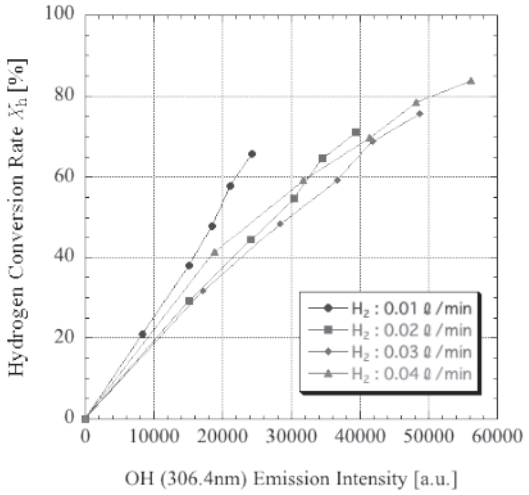

Fig. 1. Dependence of hydrogen conversion rate on OH emission intensity.

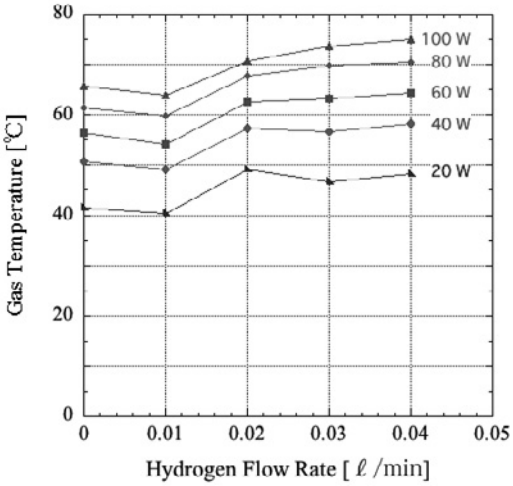

Fig. 2. Dependence of gas temperature on hydrogen gas flow rate during hydrogen combustion.