§4. Comparison between Hydrogen and Hydrocarbon Combustion Processes in Atmospheric Pressure Microwave Plasma

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In nuclear fusion reactor buildings, tritium and tritiated carbon must be recovered in the zone. As for a tritium removal system, using heated precious metal catalyst and molecular sieve bed is well known method which offers adequate efficiency. However, there are some issue for a high-pressure drop, the use of a large amount of precious metals, and inefficient heating occur when the processing throughput is quite large. On the other hand, plasma combustion is expected to solve these problems since hydrogen and oxygen radicals are easily generated by high-energy electron and ion impacts in the plasma. In this study, we have performed hydrogen and hydrocarbon combustion experiments using an atmospheric pressure plasma generated by a 2.45 GHz microwave injection as shown in Figure 1. Small amounts of hydrogen, hydrocarbon (methane; CH4) and oxygen were mixed in the operational argon gas during discharge. In order to investigate the detail reactions during combustion, a gas chromatography system (GC), a quadrapole mass spectrometry (QMS) and an optical emission spectroscopic measurement (OES) has been utilized.

So far, hydrogen conversion efficiency has been achieved over 80% at 100W for input microwave power. We have also found the microwave input energy density is one of key parameters for combustion processes in atmospheric pressure plasma. Emission intensity of OH radical observed by the OES, which corresponds to OH density, increases with increasing the power. This results indicate the importance of OH radical in the hydrogen combustion [1,2]. It has been also found that neutral gas temperature in the plasma is much higher than the outside temperature of plasma. The high neutral gas temperature would affect to the combustion reaction [3]. In the case of CH_4, the combustion rate increases with an increase in the discharge power. The rate reaches over 90 % at more than 60W input power. During the methane combustion, gas concentration measured by the GC shows that main component in the gas after combustion is identified as CO_2, which rises with increasing the input power. On the other hand, hydrogen molecule is drastically decreased with increase in the input power. Emission intensity of OH radical increases with increasing the power. These results also indicate the importance of OH radical in the methane combustion. However, the OH concentration has the maximum around 20-30 % of O_2 density as shown in Fig. 2. Moreover, the dependence of CH_4 combustion rate on O_2 concentration under the fixed discharge power indicates the peak around 5 % of O_2. The O_2 density is consistent with the optimum O_2 concentration (4 %) assuming the complete combustion reaction as follows;

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2. \quad (1)$$

These results indicate that OH radial may not contribute to the CH_4 combustion sufficiently. This tendency is different from the case of hydrogen combustion. For more detail discussion, improvement of spatial resolution of the OES measurement and introducing laser spectroscopy for evaluating plasma density and temperature are helpful.

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1) Akahane, K., Ezumi, N. et al.: Fusion Sci. Tech. **60** (2011) 1343.
2) Ezumi, N., Akahane, K. *et al*., Plasma and Fusion Research, **7**, (2012) 2401075.
3) Yoshida, T., Ezumi, N. *et al*., Fusion Sci. Tech. **67** (2015) 650.

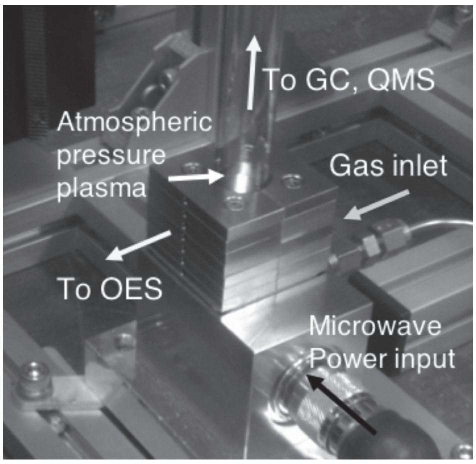

Fig.1. Photograph of the atmospheric pressure microwave plasma source for hydrogen and CH_4 combustion experiments.

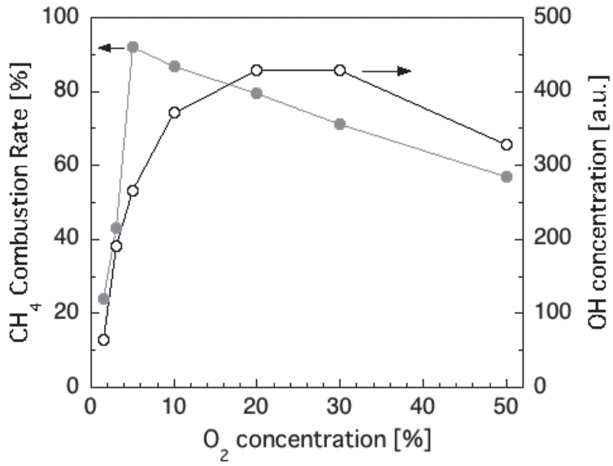

Fig.2. Dependence of CH_4 combustion rate and OH concentration during atmospheric pressure plasma discharge on O_2 concentration.