§13. Fundamental Investigation on Quenching Process of High Power Density Plasmas by Injection of Molecular Gases

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Controlling and quenching of high heat-flux plasmas by neutral gases is considered to be important for the divertor plates to avoid being thermally damaged. Thus, understanding of interactions between high power density plasma and molecular gas is desired for this purpose. Such a plasma quenching is also important for design of circuit breakers, in which high power-density plasma is quenched by molecular gas flow. The plasma quenching is influenced by the association and dissociation of molecular particles in gases. We have so far investigated such a plasma quenching efficiency of one of molecular gases CO_2 from experimental and numerical approaches. In the present report, we paid attention to CO_2 with additional molecular gas, especially H_2 gas.

Fig. 1 shows the schematic diagram of the plasma torch used in the present work. In the experiment, total gas flow rate was fixed at 100 slpm(=liters/min). Gas flow rates of Ar and additional gas were set to 90 and 10 slpm, respectively. As the additional gas, CO_2+H_2 gas with different admixture ratio was used. Gas was supplied from the upper side of the plasma torch. Input power to the rf power supply was fixed at 50 kW. Pressure in the chamber was set to 0.1 MPa.

Spectroscopic observation was carried out between 2nd-3rd coil (Position Q in Fig.1), at 10 mm below the coil end (Position R) and at 40 mm below the coil end(Position S). In the present work, we focus C_2 vibrational and rotational temperatures in high-power Ar-CO_2+H_2 induction plasmas to study plasma-quenching efficiency of CO_2+H_2 from the observed C_2 Swan spectra. Fitting the theoretically calculated spectra with the experimentally observed ones allows the determination of vibrational and rotational temperatures of C_2 molecules. Rotational temperature is considered to be close to heavy particle temperature, while vibrational temperature to electron temperature because of rates of rotational and vibrational excitation and de-excitation processes by electrons or heavy particles. In addition, a high-speed video was used to capture image of plasmas to indicate degree of shrinkage of the plasma by inclusion of molecular gases. From the image, the region of visible light emission from the plasma was estimated.

Fig.2 shows vibrational temperature T_{vib} and rotational temperature T_{rot} at positions R and S versus admixture ratio between CO_2 and H_2. From the results, T_{vib} is generally higher than T_{rot}. This is because difference between the rotational levels of C_2 molecule is quite a low (about only 0.01 eV), which produces high rate of energy transfer due to collisions with heavy particles. Thus, T_{rot} is close to the translational temperature of heavy particles. On the other hand, difference between the vibrational levels of C_2 molecules is about 0.1 eV, which causes much lower rate of energy transfer due to heavy particles than that due to electrons. From this reason, T_{vib} is considered close to the electron temperature. Another important point in this figure is that increasing H_2 admixture ratio against CO_2 hardly changes T_{vib}, although it slightly decreases T_{rot}. This implies that H_2 inclusion hardly decays the electron temperature, but it decays the heavy particle temperature.

Fig.3 shows the full width at half maximum (FWHM) for radiation intensity of visible light from the plasmas versus H_2 admixture ratio in additional gas. The FWHM decreases with increasing H_2 ratio especially for position P, indicating that H_2 inclusion causes shrinkage of the high light emission region form the plasma.

Reference

[1]Uchida,T, Tanaka Y,Uesugi, Y, IEEJ **35**, No.11(2007 to be appear)

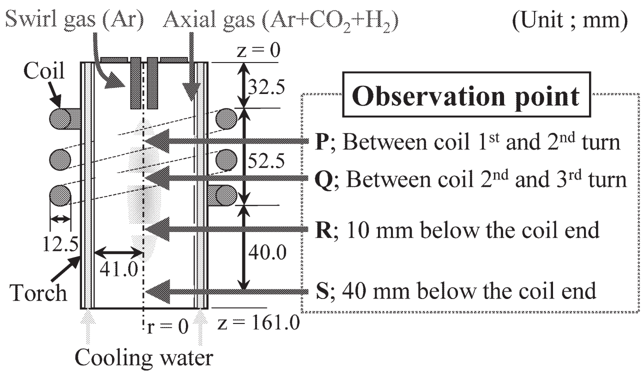

Fig.1 Plasma torch and spectroscopic observation positions.

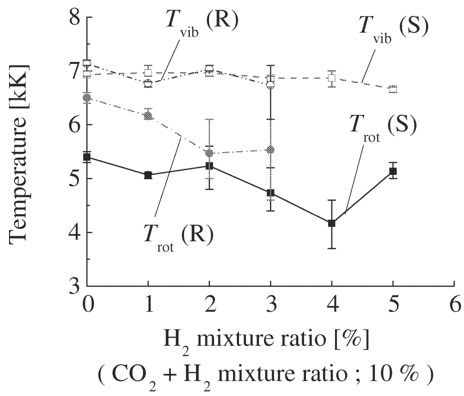

Fig.2 Vibrational and rotational temperatures of C_2 molecule versus H_2 admixture ratio.

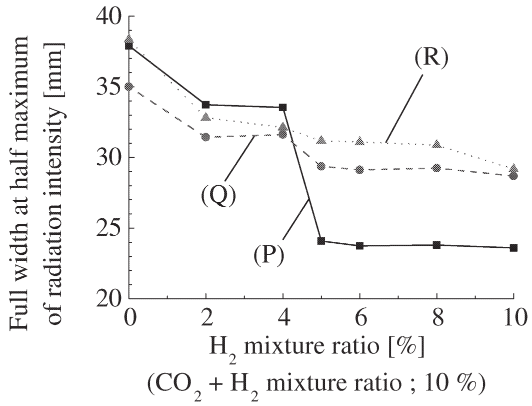

Fig.3 Full width at half maximum for radiation intensity of visible light from Ar-CO_2-H_2 plasmas versus H_2 admixture ratio.