§15. Plasma-Quenching Efficiency of Molecular Gas Inclusion on Temperature of Ar Induction Thermal Plasmas

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In the tokamak fusion devises, the divertor is exposed to high-power density plasma. Thus, it is important to control heat flux from the high power-density plasma onto the divertor plate. Quenching of the high power-density plasma is deeply related with the plasma-quenching efficiency of gases surrounding the divertor plate. On the other hand, plasma-quenching efficiency of high power-density plasma is essential in the arc interruption phenomena in high-voltage circuit breakers, in which an arc formed between the electrodes is quenched by the molecular gas flow and by the ablated gas flow from the polymer nozzle. Thus, it is very important to investigate the quenching efficiency of molecular gases on the high-power density plasma fundamentally.

In our previous work, we used the inductively coupled plasma technique to investigate the plasma-quenching efficiency of various molecular gases for the purpose of finding arc quenching medium in a environmentally-friendly circuit breaker, and found that CO_2 has a high plasma-quenching efficiency compared with other natural environmental-friendly gases such as N_2 O_2, Air, Ar and He [1]. In this experiment, the CO_2 inclusion was found to decrease Ar excitation temperature and the diameter of the high-power plasma region.

The present work focuses CO_2 +H_2 and CO_2+N_2 to see possible enhancement of the plasma-quenching efficiency of gas with additional molecular gas. Furthermore, we study effects of molecular gases on the dynamic behavior of thermal plasmas. For this study, we used pulse-modulated induction thermal plasma (PMITP) system. This system can produce a modulated coil-current sustaining the induction thermal plasma. The modulation of the coil current makes the induction thermal plasma under transient state. The experimental conditions are as follows: Input power to inverter power supply is 15 kW, pressure in the chamber is 230 torr, Ar gas flow rate is 98 L/min, and additional molecular gas flow rate is 2 L/min. Shimmer current level (SCL), which is a ratio of higher current level to lower current level in modulation current, is set to 100 to 50%. The gases CO_2, H_2, N_2, and CO_2+N_2, CO_2+H_2 were selected as additional molecular gases. Spectroscopic observation was carried out to find the transient behavior of the pulse-modulated induction thermal plasma with molecular gases. The measured wavelengths are 703 and 714 nm for Ar I lines and 709 nm for the neighbor continuum. Argon excitation temperature was estimated by the two-line method using the Ar I lines.

Fig. 1(a) shows the pulsing signal, (b) the radiation intensity of Ar I line at 714 nm, (c) and (d) the Ar excitation temperatures. The SCL is 80%. It is seen that the radiation intensity and Ar excitation temperature are modulated according to the modulation of the coil current. The maximum value of the radiation intensity in Ar-CO_2 plasma is lowest among the present gas condition. For Ar excitation temperature, particularly inclusion of CO_2 or CO_2+N_2 causes large decay in the minimum value of Ar excitation temperature in decaying process. However, we found in the experiment, Ar+CO_2+H_2 PMITP cannot be sustained even for higher SCL.

Fig.2 shows the sustaining region of the PMITP with CO_2, CO_2+H_2 and CO_2+N_2 versus duty factor and SCL. Duty factor is defined as a ratio of the time with higher current amplitude to a modulation cycle time. The curves indicate the boundaries between sustain and extinction of the PMITP. The right hand side of the curve indicates the sustaining region of the PMITP. From this figure, Ar+CO_2+H_2 PMITP has a narrower sustaining region than Ar-CO_2 and Ar-CO_2+N_2, which may represent CO_2+H_2 has a higher plasma-quenching efficiency than the others.

Reference

[1] Tanaka, Y.,Sakuta T., J.Phys.D:Appl.Phys. **35**, (2002) 2149

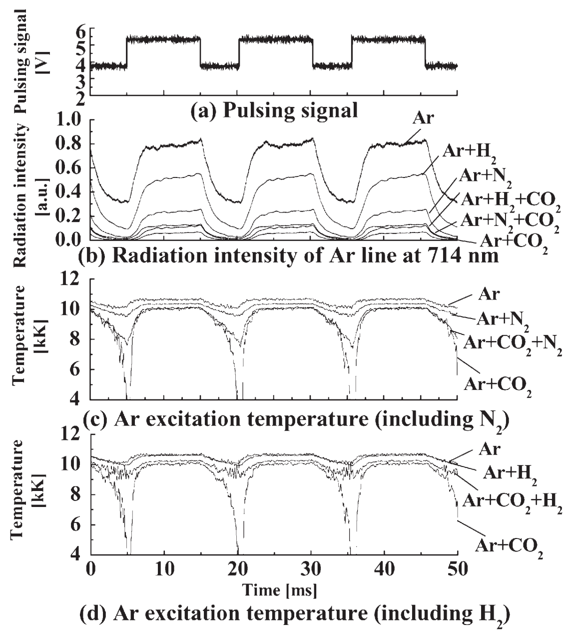

Fig.1 Time evolution of (a) pulsing signal, (b) radiation intensity of Ar line at 714 nm, (c)and (d) Ar excitation temperature.

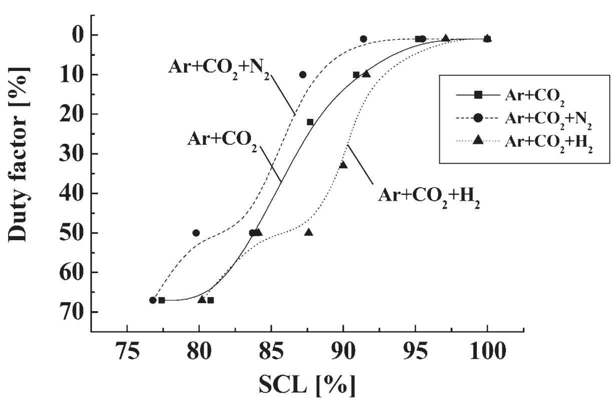

Fig.2 Sustaining region of pulse-modulated induction thermal plasmas with molecular gases.