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A study on temperature decay of thermal plasma due to polymer ablation using induction thermal plasma technique

Toshiaki Sakuyama[1, 2], and Yasunori Tanaka[2]
[1] Hitachi, Ltd., [2] Kanazawa University
e-mail (speaker): toshaki.sakuyama.cj@hitachi.com

In this paper, temperature decay of thermal plasmas due to polymer ablation was investigated using the inductively coupled thermal plasma (ICTP) irradiation technique. The Ar-ICTP was directly irradiated to the polymer bulk materials located downstream of the thermal plasma. Spectroscopic observation was conducted to obtain the vibrational and rotational temperatures of C_2 molecule in the ablated polymer gas. For various kinds of polymer materials, the temperature decay due to polymer ablation was evaluated from the experimentally obtained temperatures.

Fig. 1 shows the schematic of the experimental setup consisting of a plasma torch, a specimen holder and a spectroscopic observation system. From the top of the torch, Ar sheath gas was injected along the wall of the inner quartz tube at a flow rate of 30 slpm (=standard liters per minute). A cylindrical polymer specimen was mounted on the specimen holder. The specimen's diameter and thickness are 15 mmϕ and 5 mm, respectively. The pressure inside the chamber was 760 torr. The input power to the thermal plasma was 7.5 kW. Spectroscopic observation was carried out at 1.25, 3.75, 6.25, and 8.75 mm above the specimen surface. For specimens, PTFE (polytetrafluoroethylene), PE (polyethylene), PMMA (polymethylmethacrylate), PA66 (polyamide 66) and PA6 (polyamide 6) were used. These materials are widely adopted as electrical insulation in circuit breakers.

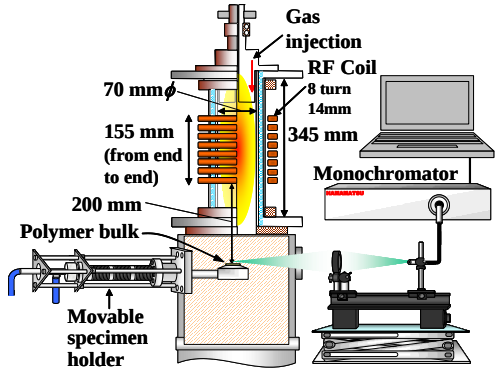

Figure 1 Schematic diagram of experimental setup.

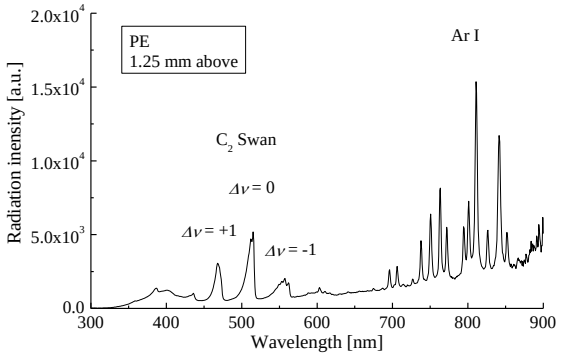

Figure 2 Measured spectra for PE bulk

Fig. 2 shows the emission spectra measured at 1.25 mm above the specimen surface of PE. Spectra of C_2 Swan system were observed in the wavelength range of 400–600 nm, while Ar spectral lines were also observed in the range of 700–800 nm. On the other hand, the emission coefficient of C_2 Swan system was theoretically calculated as functions of rotational temperature T_{rot} and vibrational temperature T_{vib} under the assumption that population of exited molecules follows the Boltzmann distribution. The T_{rot} and T_{vib} can be determined by fitting the calculated C_2 spectra to the measured ones.

Fig. 3 shows axial distribution of T_{vib} and T_{rot} estimated from the C_2 spectra in ablated polymer gas. This figure also includes the Ar excitation temperature T_{ex} which was determined by the Ar atomic spectral lines using two-line method in case of titanium specimen instead of polymer bulk as no ablation case for comparison. The T_{rot} seems to be closer to the heavy particle temperature since the energy transfer rate between rotational energy levels is enough high by heavy particles collisions. Whereas T_{vib} can be close to the electron temperature rather than the heavy particle temperature because a difference in vibrational levels is as large as 0.1 eV. On the other hand, T_{ex} is regarded almost equivalent to the electron temperature in the present experimental condition. Therefore, it is reasonable to compare T_{vib} in polymer ablation case with T_{ex} in no ablation case, in order to investigate the temperature decay due to polymer ablation.

As seen in Fig. 3, T_{vib} is almost around 4000 K for all polymer cases, whereas it is 4500 K lower than the T_{ex} of 8500 K in no ablation case at 1.25, 3.75, 6.25, and 8.75 mm above the specimen surface. As a result, the polymer ablation causes the temperature decay of Ar thermal plasma by 4000 K. This temperature decay may result from the energy consumption for ablation of solid-state polymer and dissociation of ablated polymer gas.

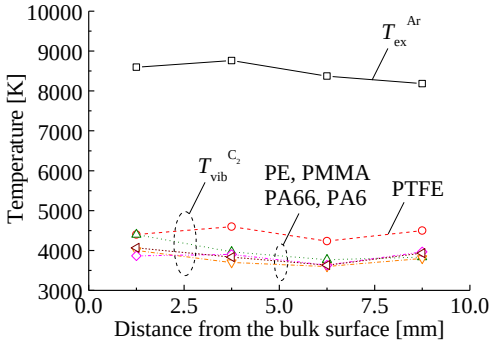

Figure 3 Axial distribution of T_{ex} of Ar and T_{vib}.