22P083-R

Observation on Decaying Process C_2 molecular spectra in Polymer Ablation Arcs under Free Recovery Condition

フリーリカバリ状態における高分子材アブレーションアークの
C_2 分子放射強度の減衰過程観測

Yohei Horikawa, Yasunori Tanaka and Yoshihiko Uesugi
堀川洋平, 田中康規, 上杉喜彦

Kanazawa University, Kakuma-machi, Kanazawa, 920-1192, Japan
金沢大学 〒 920-1192 金沢市角間町

In this report the experimental results were presented on the decaying process of polymer ablation arcs under free recovery condition. The polymer ablation arcs can be seen in low-voltage circuit breakers and arcing horns etc. Understanding of polymer ablation phenomena is important to elucidate the current interruption processes in the above breakers. In the present experiments, PTFE and PA66 were used as polymer materials. Spectroscopic observation was conducted to measure C_2 radiation intensity and its time evolution. Results indicated that PA66 causes a much higher decay of the polymer ablation arcs than PTFE.

1. Introduction

The polymer materials are usually used for polymer moulded case in a moulded case circuit breaker (MCCB), or for a gas flow nozzle in a high-voltage circuit breaker. These polymer materials were exposed by the arc plasma, which is formed between the electrodes in a circuit breaker during high current interruption process. In this case, the polymer is much ablated, which affects the interruption performance of the circuit breaker. Recently, a MCCB and an arcing horn have been developed, which effectively utilize the polymer ablation phenomena to enhance their interruption capability. However, the polymer ablation phenomena are much complicated involving mass, momentum and energy tranfer between the arc plasma and solid polymer. The contamination of polymer ablated vapors also remarkably changes thermodynamic and transport properties of the arc plasma.

Until now, the authors have paid attention to development of a polymer ablation model for arc plasmas [1, 2]. This model solves the mass, momentum, energy conservation equations of the arc plasma as well as mass coservation equation of polymer vapor. The net polymer ablated flux was also estimated using saturation vapor pressure and the redeposition flux from the arc to the polymer surface. Using the developed model, we predicted the arc voltage and the ablated polymer mass in the steady state condition. These results fairly agreed with the experimental results. However, the arc interruption process is essentially under transient state. Thus, it is necessay to study transient process of polymer ablation arcs.

This report describes the experimental results on the decaying process of the polymer ablation arcs under free recovery condition. The arc current was changed stepped down from 50 A to 0 A to study the arc decaying process. The time evolution in the radiation intensity of C_2 spectra in polymer vapor were measured for different polymer materials.

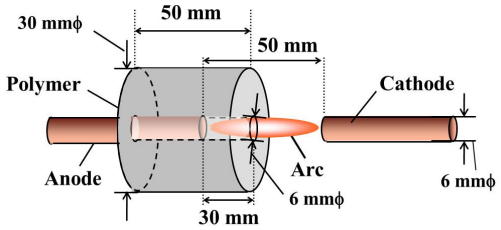

Fig. 1: Arc model.

2. Observation of an polymer ablation arc under free recovery condition

Fig. 1 shows a schematic of the polymer ablation arc device. An arc plasma is formed between two iron electrodes. The diameter of the electrode is 6 mm. The distance between the electrode is 50 mm. One of the electrode is surrounded with a polymer cylindrical tube with inner diameter of 6 mm. The distance between the electrode surface inside the polymer and the outlet of the polymer is 30 mm.

Fig. 2 illustrates the experimental circuit. The arc device is connected to the dc current source. The experiments were made as follows: An arc plasma was ignited between the electrode using a copper wire fuse. Through this wire, the electric current of 50 A was supplied by the dc current source, and then the arc plasma is established between the electrode. During the arc forming, there occurs polymer ablation, which causes a strong gas flow injection from the polymer outlet. At 0.2 s after the arc ignition, an insulated gate bipolar transistor (IGBT) connected parallel to the arc device were ignited. Then, the arc current decreases suddenly from 50 A to 0 A.

In this experiment, we have chosen two polymer

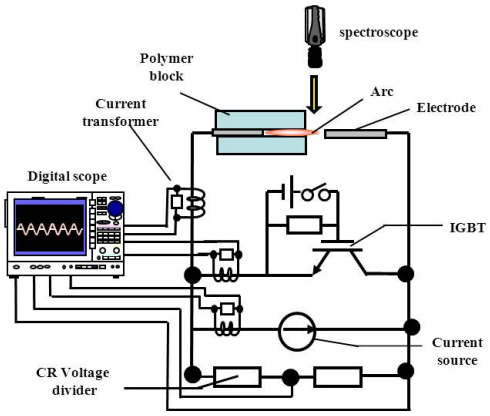

Fig. 2: Layout of experimental circuit.

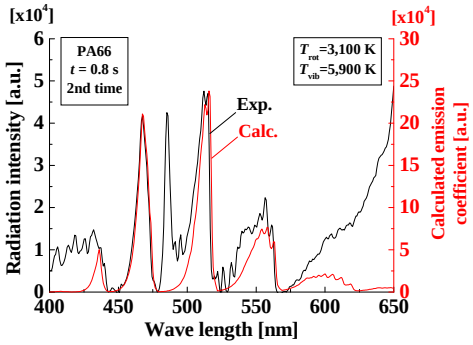

Fig. 3: Observed spectra(PA66).

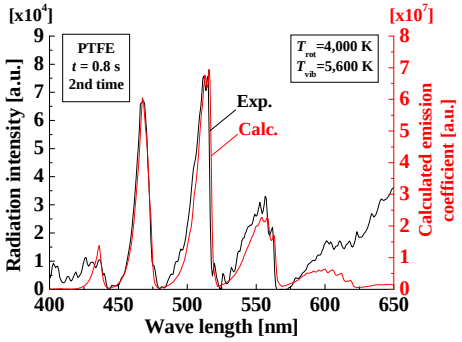

Fig. 4: Observed spectra(PTFE).

materials PA66$[-C_{12}H_{22}O_2N_2-]_n$ and PTFE$[-C_2F_4-]_n$. Spectroscopic observation was carried out around the outlet of the polymer tube. Observation area with a diameter of 5 mm was set around the center axis at the outlet. The polychromator was used to confirm presence of C_2 spectra in polymer vapor ejected under steady state condition. A monochromator with a photomultiplier tube were adopted to measure the time evolution in the radiation intensity of specified C_2 lines under free recovery condition in transient state.

3. Results and discussions

3.1. Spectra observed under steady state condition

Figs. 3 and 4 show the observed spectra at the outlet of the polymer tube under steady state condition. As seen, C_2 Swan system around wavelengths of 450–550 nm was clearly observed both for PTFE and PA66. The C_2 molecules are present in polymer vapor according to the calculated equilibrium composition. In these figures, theoretically calculated C_2 spectra were fitted to the experimental results, evaluating the rotational and vibrational temperatures. The PA66 vapor has a lower rotational and vibration temperatures than the PTFE vapor.

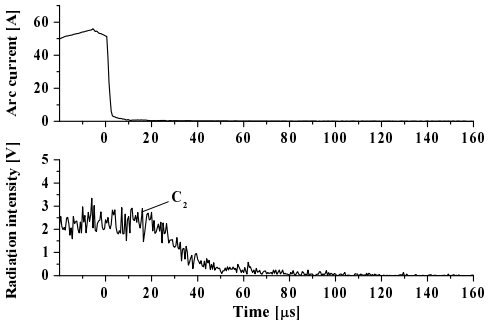

Fig. 5: Radiation intensity of C_2 in PA66 ablated arc.

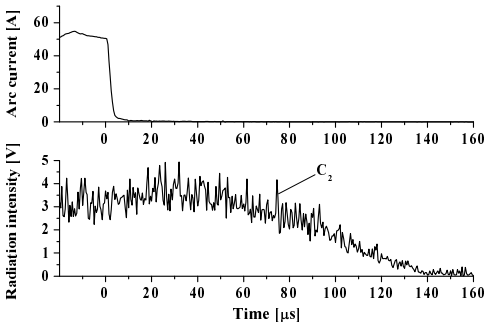

Fig. 6: Radiation intensity of C_2 in PTFE ablated arc.

3.2. Time evolution in C_2 radiation intensity

From this observation results in Figs. 3 and 4 , we selected C_2 spectral intensity at 464.6 nm to measure. Figs. 5 and 6 presents the current and C_2 intensity before and after the current was changed down to 0 A. The t=0 μs on the vertical axis corresponds to the timing of the current down. In case of PA66, the C_2 radiation intensity was kept until t=20 μs, but it decayed rapidly after that. On the other hand, the C_2 radiation intensity hardly changed until t=60 μs for PTFE arc , and then it gradually decreased with time. Comparison with these figure implies that PA66 provides much a higher decay of the arc plasma than PTFE. This tendency can be obtained also by numerical approach.

4. Conclusion

This report presents the experimental results on the decaying process of polymer ablation arcs under free recovery condition. PTFE and PA66 were used as polymer materials. Spectroscopic observation was conducted to measure C_2 radiation intensity and its time evolution. Results indicated that PA66 causes a much higher decay of the polymer ablation arcs than PTFE.

References

[1] Y. Takezawa, et al,The Papers of Tech. Meeting. Switching & Protect. Eng., IEEJ, ED-10-044, SA-10-060, SP-10-011, 2010.

[2] Y. Horikawa, Y. Tanaka, Y. Uesugi,The Papers of Tech. Meeting. Switching & Protect. Eng., IEEJ, ED-11-065. SA-11-038, SP-11-011, 2011.