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Characterization of Multiphase AC Arc by High-Speed Visualization

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Thermal plasmas with high energy have been used in various industrial fields. Multiphase AC arc is expected as a new technology for the production of functional nanomaterials and industrial waste treatment. Because it possesses many advantages such as high energy efficiency, large plasma volume, easy to scale-up, and low equipment cost. Controllability against the fluctuation of spatial and temporal temperature distribution of multiphase AC arc is important in order to realize high quality and reliable processing. In the previous studies, the effects of working pressure and driving frequency on arc behavior and temperature distribution were clarified by dual wavelength spectroscopy using a high-speed camera.[1-3] The objective of this study is to clarify the effect of the number of electrodes and phases on arc behavior and temperature distribution in a multiphase AC arc.

The schematic diagram of multiphase AC arc generator with measurement system and plane view of electrode arrangement are shown in Fig. 1. Arc is generated between the electrodes by supplied AC power with different phases. The arc behavior and temperature were investigated by the observation system consisting of a high-speed video camera and band-pass filters. The temperature was calculated by Boltzmann plot method. Comparisons were carried out between 3 electrodes with 3-phase, 6 electrodes with 6-phase, and 12 electrodes with 12-phase. These three kinds of configurations are defined as 3-phase, 6-phase, and 12-phase AC arc respectively.

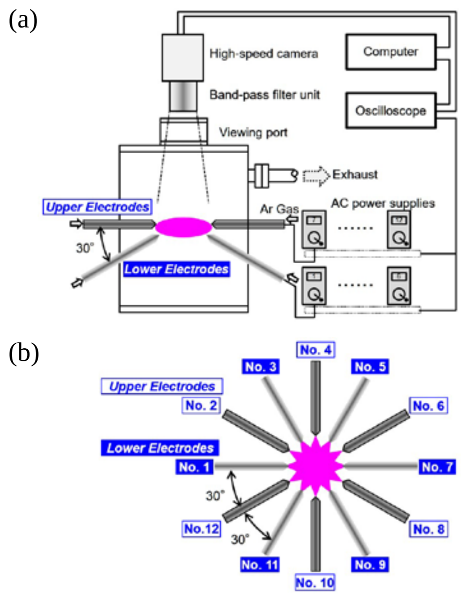

Fig. 1. (a): Schematic diagram of the multiphase AC arc generator with measurement system. (b): Plane view of electrode arrangement.

Electrodes No. 1, 5, and 9 were used in 3-phase, all lower electrodes were used in 6-phase, and all 12 electrodes were used in 12-phase AC arc. The AC phase differences between adjacent electrodes were 120, 60, and 30 degrees, respectively. The working pressure was set at 100 kPa of argon gas and the current for each electrode was 100 A. The distance between facing electrodes was set at 100 mm.

The arc temperature fluctuates in the range of $7.0x10^3$ to $1.0x10^4$ K during the cathodic period and $7.0x10^3$ to $9.0x10^3$ K during the anodic period at all configurations. The arc from the cathode is observed to be more contracted than from the anode. This contraction increases the current density of the arc and promotes heating by Joule heat. The high temperature of approximately $1.3x10^4$ K is observed around the electrode. There was no significant difference in arc temperature under all conditions, but there was a large difference in arc existence distribution.

The arc existence probability was obtained from the time occupancy with arc emission in one AC cycle. The distributions of existence probabilities in different number of phases are shown as Fig. 2. Arc exists only in the part extending straight from the electrode tip at 3-phase AC arc. The uniformity increases with increasing phase number. At 12-phase AC arc, the arc exists almost entirely, and the area where the arc always exists is found in the center. The influence of the interaction between adjacent arcs increases as the number of electrodes increases, and the uniformity increases due to the swing of the arc. Therefore, 12-phase AC arc with a wide arc region is suitable for the material processing.

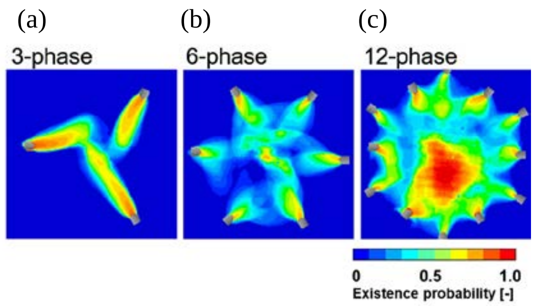

Fig. 2. Arc existence probabilities: (a): 3-phase; (b): 6-phase; (c): 12-phase AC arc.

References

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