Thermal plasma generation for innovative applications

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Abstract: Innovative thermal plasma generation method was successfully developed with diode-rectification technique. A multiphase AC arc generation with diode-rectified electrodes improves electrode erosion characteristics. High-speed visualization of the fluctuation phenomena in the arc was conducted. Obtained remarks suggest that mass production of nanomaterials with negligible impurity can be achieved.

1. Introduction

Innovative thermal plasma sources have been successfully developed based on diode-rectification technique. Thermal plasmas can offer unique advantages such as high temperature, high chemical reactivity, and rapid quenching rate. Industrialization of thermal plasma processing can be realized by further development of thermal plasma sources in terms of the energy efficiency, scaling up, etc. [1]. Recent improvement of semiconductor switching device enables to develop innovative thermal plasma sources. Attractive thermal plasma source of a multiphase AC arc with diode-rectified AC system is developed [2]. In the presentation, the generation and visualization of fundamental phenomena in the multiphase AC arc will be presented.

2. Experimental

Representative snapshots of the multiphase AC arc are presented in Fig. 1. Twelve diodes are placed between the electrodes and transformers. Thus, the electrodes were divided into pairs of cathode and anode, namely bipolar electrodes. Each electrode consists of cathode made of water-cooled 2wt%-La_2O_3 W rod with 6.0 mm in diameter and anode made of water-cooled Cu. Twelve pairs of electrodes are symmetrically arranged at angle of 30 deg. Diode-rectified multiphase AC arc was generated among 12 bipolar electrodes in the chamber which was filled by Ar, Ar-N_2, Ar-H_2 mixture at atmospheric pressure.

Spatiotemporal characteristics of the arcs were systematically investigated. Two high-speed cameras with band-pass filters were placed to the plasma chamber and synchronized measurements were conducted from top and side views. Obtained arc images at two different wavelengths at typical framerate of 10,000fps were converted into temperature distributions based on theoretically obtained temperature dependence of emission coefficient ratio at corresponding wavelengths with a consideration of both line and continuous spectra under LTE assumption.

3. Results and Discussion

Figure 2 shows the visualized temperature distribution during 10 ms under 10% N_2 condition. Complicated and fluctuated arc can be observed. Temperature near the electrode is higher than other regions. The plasma temperature at the center is fluctuated in the range from 7,000 to 14,000 K. Moreover, interesting arc instability with omega-shaped structure was visualized from side camera observation. One of the reasons for this instability is arc pinch effect when the molecular gases are added into Ar. The dissociation of molecular gas leads to the quenching effect at the arc fringe, resulting in higher current density in the arc. Consequently, Lorentz force driven fluctuation occurs at higher N_2 concentration.

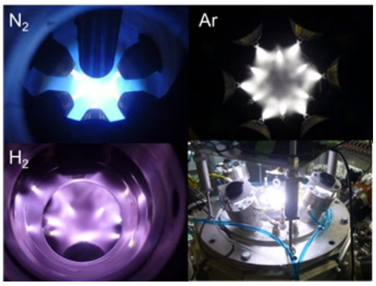

Fig. 1. Representative snapshots of diode-rectified multiphase AC arc at different ambient atmosphere.

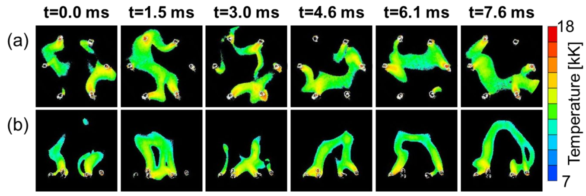

Fig. 2. Temperature distributions measured (a) from the top and (b) from the side during half AC cycle in 90%vol Ar-10%vol N_2 arc.

4. Conclusion

In the present study, the innovative thermal plasma generations were developed. Fundamental phenomena were successfully visualized by originally developed high-speed camera system. Obtained remarks enable us to understand fundamental phenomena and to control the high temperature plasma region.

Acknowledgement
This work was partly supported by MEXT/JSPS KAKENHI with Grant Nos. JP22K03587, JP24K00621, and JP24H00036.

References

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