2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

High-Speed Measurement of Electrode Temperature of Diode-Rectified Multiphase AC Arc

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A multiphase AC arc (MPA) is attractive thermal plasma source due to its advantages such as high energy efficiency. However, electrode erosion is one of the most important issues to be solved. Many efforts to understand erosion mechanism had been conducted. High-speed visualization revealed that erosion due to droplet ejection was dominant at cathodic period, while the erosion due to evaporation was dominant at anodic period [1].

An innovative diode-rectified MPA (DRMPA) has been developed to overcome above-mentioned electrode issue [2]. Electrode erosion in the DRMPA with bipolar electrodes was drastically improved on the basis of the separation of AC electrode into a pair of cathode and anode. However, erosion mechanism in the DRMPA has not been clarified yet. The purpose of the present study is to understand the electrode erosion mechanism in the DRMPA. Influence of doped oxide on tungsten-based cathode was investigated.

Schematic illustrations of the electrode configuration for the DRMPA and the MPA are shown in Fig. 1. Each electrode in the DRMPA consists of tungsten-based cathode with 3.2 mm in diameter and copper anode with 20 mm in diameter. Six pairs of the electrodes are symmetrically arranged at the angles of 60 deg. Odd numbered cathodes are placed above the corresponding anodes, whereas even numbered anodes are placed above the cathodes. DRMPA was generated among these electrodes in argon atmosphere. Pure tungsten and 2wt%-thoriated tungsten were compared to understand the role of the doped oxide on tungsten erosion.

Electrode phenomena and arc behavior were visualized by a high-speed camera. Electrode temperature during arc discharge was measured on the basis of the two-color pyrometry. Only thermal radiation from the electrode surface was visualized by the high-speed camera with band-pass filters. Two band-pass filters at 785 and 880 nm were employed to eliminate the strong line emissions from the arc. Frame rate and shutter speed were 10,000fps and 20 μs, respectively.

Figure 2 shows the arc behaviors of the DRMPA and the MPA. Electrodes No. 5 and 6 were in the cathodic period at 0.0 ms, while electrode No. 2 and 3 were in the anodic period. In the case of the MPA, both the cathode jet and anode jet were observed near the electrode. In the case of the DRMPA, the anode jet was not observed, while cathode jet was clearly observed. These different behaviors of the anode jet originated from the negligible anode evaporation in the case of the DRMPA.

Figure 3 shows the representative snapshots of surface temperature in the DRMPA and the MPA for pure tungsten and 2wt%-thoriated tungsten cathode. Electrode temperatures of pure tungsten in both the DRMPA and the MPA were higher than the melting point of tungsten. In contrast, electrode temperature of the thoriated tungsten was lower than that of pure tungsten. In particular, that in the DRMPA was lower than the melting point of tungsten, while that in the MPA was higher than the melting point.

The reason for the lower temperature of the thoriated tungsten in the DRMPA can be explained by thin liquid layer of thoria formed at the electrode tip. Thermionic emission occurs from the thoria surface with a work function of 2.55 eV, hence the electrode erosion from thoriated tungsten in the DRMPA was significantly lower than that in the MPA.

The innovative DRMPA was successfully developed. Electrode erosion mechanism was clarified based on the high-speed visualization.

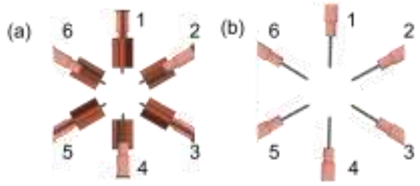

Fig. 1. Electrode configurations for the DRMPA (a) and the conventional MPA (b).

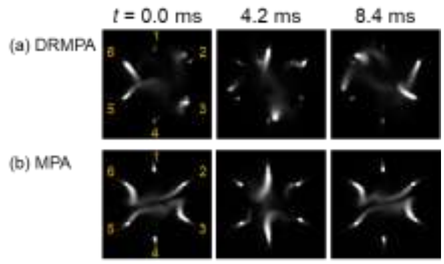

Fig. 2. High-speed snapshots of the DRMPA (a) and the conventional MPA (b).

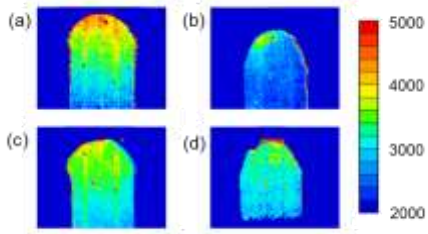

Fig. 3. Representative snapshots of electrode temperature for pure W in DRMPA (a), ThO_2-W in DRMPA (b), pure W in MPA (c), and ThO_2-W in MPA (d).

References

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[2] M. Tanaka, et al., J. Phys. D, 50 (2017) 465604.