低温処理のための回転式大気アークジェットの開発

Development of rotating ambient-air arc jet for low-temperature treatment

名城大 [1]，大阪市立大 [2] ○(PC)ウラディスラフ・ガマリェエフ [1]，(M1)岩田 直幸 [1]，
呉準席 [2]，平松美根男 [1], 伊藤昌文 [1]

Meijo Univ. [1], Osaka City Univ. [2], ○(PC)Vladislav Gamaleev[1], (M1)Naoyuki Iwata[1],

Jun-Seok Oh[2], Mineo Hiramatsu[1], Masafumi Ito[1]

E-mail: vlad@meijo-u.ac.jp

1. Introduction

Recently plasma activated water (PAW) is attracting a lot of attention owing to a huge number of possible agriculture and medical applications such as seed germination promotion and disinfection.[1] There are many ways to produce PAW, such as atmospheric pressure plasma jets (APPJ) and dielectric barrier discharge (DBD); however, generation of this type of discharges typically requires expensive high voltage power supply and special gasses (such as He or Ar) to generate the plasma.[2] Turbulent gas flow and small size are making treatment of large targets and powders impossible. Moreover, requirement of special gasses and problems with scaling are limiting conventional DBD APPJ to laboratory studies and research applications. Taking into account problems described above, thermal arc discharges seem to be promising for the development of APPJ considering high density of plasma, wide range of possible parameters of the discharge and possibility of generation of the discharge in ambient air, which allows to perform plasma irradiation using simple experimental setup and reduce treatment costs. Moreover, arc discharge is easily scalable, which could be essential for medical and agricultural applications. However, the high temperatures of ambient-air plasmas lead to serious damages and burning of samples. To overcome the problems, we have developed portable rotating arc generator operated using ambient air flow and investigated the effects of experimental conditions on properties of the discharge and generated in the discharge species.

2. Experimental procedure

Arc discharge was generated using flyback transformer operated by a push-pull generator. Discharge gap was organized between rod and ring electrodes by placing tip of the rod electrode to a center of the ring electrode. Ring electrode was surrounded by toroidal magnets for rotation of the arc in the discharge gap. Custom cooling system was developed to prevent heating of the electrodes. Discharges were generated in ambient air with flow rate of air varied in a wide range.

3. Results and discussion

Using the setup described above, it was succeeded to generate rotating arc discharge in ambient air at various flow ratios using small input power (below 50 W). Type of the discharge was changed from non-equilibrium filamentary gliding ark to equilibrium arc discharge with increase of input power. Change of type of discharge was clearly observed in the OES spectra and current and voltage waveforms. Discharge parameters and gas flow ratio were tuned to prevent the electrodes heating and keep gas at room temperature after the interaction with the plasma. It was succeeded to generate stable rotating arc discharge at small air flow ratio (0.25-0.5 slm) and low input power (35W). Low flow rate of air during operation allows to overcome problem with turbulence typically observed in conventional APPJs, which could be essential for treatment of large samples and powders.

Species generated in plasma were analyzed using optical emission spectroscopy (OES) and quadrupole mass spectrometry. Effect of input power and flow rate on the plasma parameters and generation of species were studied and optimized. Rotating arc jet was applied to treatment of water and concentrations of RONS in produced PAW were analyzed using VUV absorption spectroscopy and deconvolution of absorption peaks. It was found, that concentrations of RONS after treatment using ambient-air arc jet was more than 100 times higher than that of PAW produced using conventional APPJs operated with He gas and the same irradiation time.

Acknowledgments

This work was supported by the MEXT-Supported Program for the Strategic Research Foundation at Private Universities (S1511021).

References

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