3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Electrical, optical, and physicochemical behaviors of atmospheric pressure plasma jet generated in open air

Keigo Takeda[1], Kenji Ishikawa[2], Takayuki Tsutsumi[2], Hiroki Kondo[2],
Makoto Sekine[2], Masaru Hori[2]
[1] Department of Electrical and Electronic Engineering, Meijo University,
[2] Center for Low-temperature Plasma Science, Nagoya University,
e-mail (speaker): ktakeda@meijo-u.ac.jp

Low-temperature plasmas have been applied to bio and medical fields, and the plasma biomedical technology has been studied by many research groups as new applications of low temperature plasma. Non-thermal atmospheric pressure plasma jets (APPJs) are frequently used for the treatments of biomedical samples. In the treatments, and the treatments with APPJ are carried out in the open air condition and the biomedical samples are typically located in the effluent region far from the main discharge of APPJ. Reactive species generated in gas phase play important roles in the plasma biomedical applications. Under the open air condition, the reactive species and the high energy photons are generated in gas-phase due to entrainment of ambient air into APPJ, and then the reactive species instantly react with other species in the gas-phase because of the collisional reactions of species with high frequency in atmospheric pressure. The gas-phase reactions affect the composition of the reactive species in the APPJs and generate many different species originated from atmospheric molecules in the gas-phase. As results, under such conditions, the reactions between the APPJ and the sample are very complex and make it difficult to understand the mechanisms. Therefore, the spatial behaviors of reactive species generated by the APPJ in open air condition are strongly required to be measured for understanding the reaction mechanism.

In our group, a high density APPJ with AC power supply, which can offer electron density as high as 10^{15} cm^{-3}, has been developed [1,2]. Using the AC-excited APPJ, the plasma biomedical applications have been investigating and very interesting results such as the selective killing of cancer cells over normal cells [3,4], the inactivation of *Penicillium digitatum* spores [5,6], etc. have been achieved. In previous study, in order to understand the behaviors of reactive species in the AC-excited APPJ, spectroscopic measurements have been carried out in the conditions of nitrogen or argon gas ambience [7,8]. However, in the plasma biomedical applications, plasma treatments are frequently carried out under open air condition. Therefore, in this study, the spatial behaviors of reactive species generated by the APPJ in open air condition have been measured using spectroscopic methods.

An AC-excited Ar gas APPJ was generated between two metal electrode tips, to which a 60 Hz alternating voltage was applied, under the Ar gas flow rate of 2 slm. The AC power supply provided high voltage of around 9.0 kV. In open air condition, a plasma jet was generated as a glow discharge along the gas flow direction with a length of about 8 mm from a square-shaped gas outlet slit of plasma head. In the condition, spatial distributions of ground-state O atom, nitric oxide (NO), hydroxyl (OH) radicals, and VUV emission intensity were measured as a function of a distance from the gas nozzle of APPJ source. Figure 1 shows a reaction model of reactive species generated by the AC excited Ar gas APPJ in open air based on the measurement results obtained in this study [9]. In the visible plasma plume region (Distance ≤ 8 mm), the O atom density was relatively high at 10^{13} cm^{-3} due to dominating electron collisional dissociation of O_2 originating from ambient air. NO radical density continue to increase with the increase in distance until at least 10 mm distance. This rise is due to increase in amount of ambient N_2 diffusion into the APPJ. N_2 dissociation and subsequent recombination with O atom generates NO radical. Measurements of VUV light emission show that light intensity was decreased by absorption due to ambient air diffusing into the plasma plume. These results indicate the composition of the species is dependent on the distance from the APPJ source along the gas flow direction of APPJ.

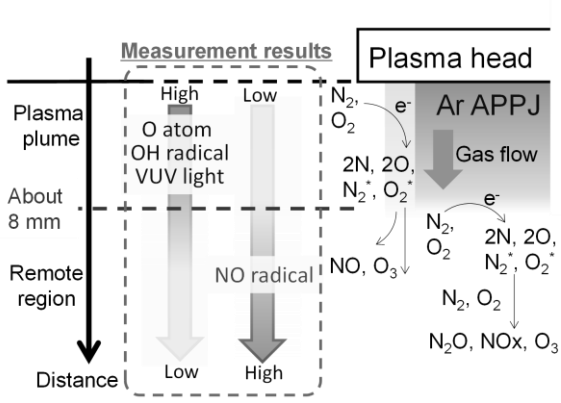

Fig. 1 Reaction model of gas-phase species generated by the AC-excited Ar gas APPJ in open air condition.

References

[1] M. Iwasaki, et al., Appl. Phys. Lett., 92 (2008) 081503.
[2] F. Jia, et al., Appl. Phys. Express, 4 (2011) 026101.
[3] S. Iseki, et al. Appl. Phys. Lett., 100 (2012) 113702.
[4] H. Tanaka, et al., Plasma Medicine, 3 (2013) 265.
[5] S. Iseki, et al., Appl. Phys. Lett. 96 (2010) 153704.
[6] S. Iseki, et al., Appl. Phys. Express 4 (2011) 116201.
[7] K. Takeda, et al., J. Phys. D: Appl. Phys., 46 (2013) 464006.
[8] F. Jia, et al., Plasma Source Sci. Technol., 23 (2014) 025004.
[9] K. Takeda, et al., J. Phys. D: Appl. Phys., 50, (2017) 195202.