22E06

Dynamics of Atmospheric Pressure Microwave Plasma Torch
大気圧マイクロ波プラズマトーチの動的挙動

Naomichi Ezumi[1], Takahiro Koide[1], Yuki Hayashi[1], Kazuhiko Akahane[1], Shinya Shiozawa[1], Keiji Sawada[2] and Noriyasu Ohno[3]
江角直道[1], 小出嵩大[1], 林祐貴[1], 赤羽和彦[1], 塩沢慎也[1], 澤田圭司[2], 大野哲靖[3]

[1]*Nagano National College of Technology, 716 Tokuma, Nagano 381-8550, Japan*
[2]*Faculty of Engineering, Shinshu University, 4-17-1 Wakasato, Nagano 380-8553, Japan*
[3]*Graduated School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Naogya 464-8603*
[1]長野工業高等専門学校　〒381-8550　長野市徳間716
[2]信州大学工学部　〒380-8553　長野市若里4-17-1
[3]名古屋大学大学院工学研究科　〒464-8603　名古屋市千種区不老町

Dynamical behaviors of a plasma torch generated by microwave in atmospheric pressure have been investigated. Changes of the plasma structure and its dynamics for gas flow and discharge power have been observed by using a high-speed camera. With respect to probe measurements, we have found the strong influence of a probe electrode on the plasma torch. A probe with metal electrode has drastically disturbed the plasma structure.

1. Introduction

Many application studies using atmospheric pressure plasmas have been tackled in the fields such as surface treatment, environment, medical, light source and so on, because of the easy productivity and inexpensive facility compared with the conventional low-pressure plasmas.

So far, we have studied an atmospheric pressure plasma torch generated by 2.45 GHz microwave with a monopole antenna in order to clarify the property. In this paper, changes of plasma structure and its dynamics observed by using a high-speed camera have been shown. Furthermore, influences of probe electrode on probe measurements have been discussed.

2. Experimental Setup

Figure 1 shows a schematic diagram of the experimental apparatus for investigating the atmospheric pressure microwave plasma using a high-speed camera and an electrical probe. A solid-state microwave power supply with 2.45 GHz in frequency (Nagano Japan Radio Co. Ltd. NJZ-2450A) is connected to a plasma source through an automatic matching box. The source consists of a aluminum chassis, an aluminum antenna, a coaxial connector and a cylindrical glass tube. The inside diameter of the glass tube is 10 mm. The tube covered the surface of the aluminum chassis in the discharge region, thus a generated plasma does not interact with the metal surface except for the antenna. Argon gas is fed into the plasma discharge region through the sidewall of the plasma source. When gas flow rate is 2~4 L/min, a flame-like plasma torch with about 10 mm in length has been generated.

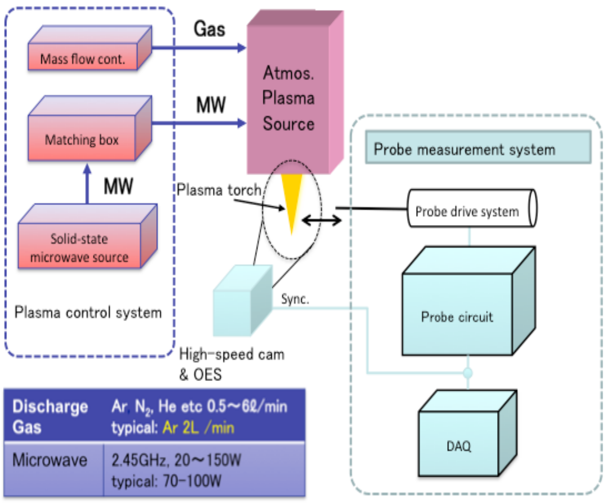

Fig. 1. Experimental setup for observing an atmospheric pressure microwave plasma torch using a high-speed camera and an electrical probe.

3. Experimental Results and Discussion

3.1 *Turbulent and Fragmental Structures [1,2]*

Increasing the gas flow rate of Ar, the structure of the plasma torch is changed. In the case of 2.0 L/min, the structure is almost stable. However, increase the gas flow rate to 4.0 L/min, the structure become an unstable state. Figure 2 shows the propagation of the unstable flame structure observed by a high-speed camera in 50000 fps. The velocity of the flame propagation is evaluated to 1.2m/s. The velocity is almost same as gas flow velocity, and then the global turbulent structure of plasma flame depends on the gas flow velocity.

The high-speed camera measurements also clarify the detail structure of the tip of the plasma torch as shown in Fig. 3. Oscillating fragmentations have been clearly observed at the tip of the torch. Each distance between fragmented elements is about 0.55 mm. In this experimental condition (4L/min, 100W), the elements moved to back with same velocity. According to the detail measurements, the oscillations have had properties for propagation velocity is proportional to the microwave power with keeping same distance between the fragments.

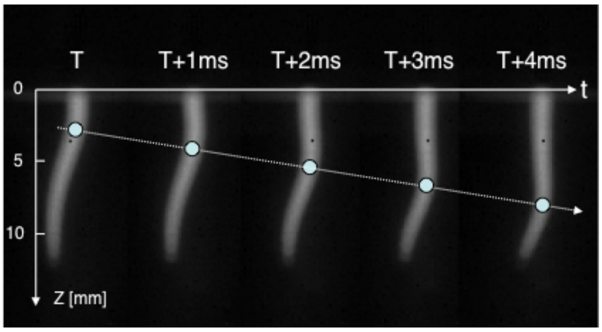

Fig. 2. Propagation of a flame structure of the plasma torch (Ar: 4 L/min, Microwave power: 100W).

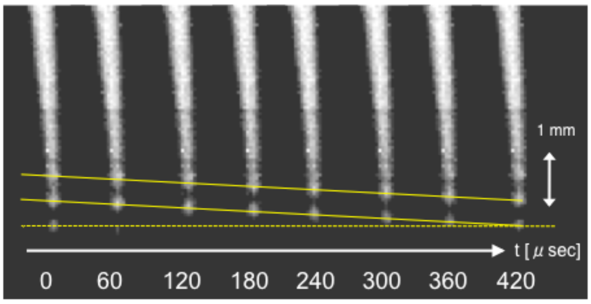

Fig. 3. Observation of a fragmental structure at the tip of the plasma torch (Ar: 4 L/min, Microwave power: 100W).

3.2 *Influence of a probe electrode [3]*

Figure 4 shows the behavior of the plasma torch when an insulator rod or a floating metal electrode put near the plasma. In the case of the insulator rod (Al_2O_3) without metal electrode, the plasma torch is bended like as avoiding the rod. In contrast, the metal electrode pulls the plasma even though it is electrically floating, and then the plasma torch completely attaches to the electrode. This phenomena suggest us a metal probe electrode become an antenna for microwave even if it is electrically floating.

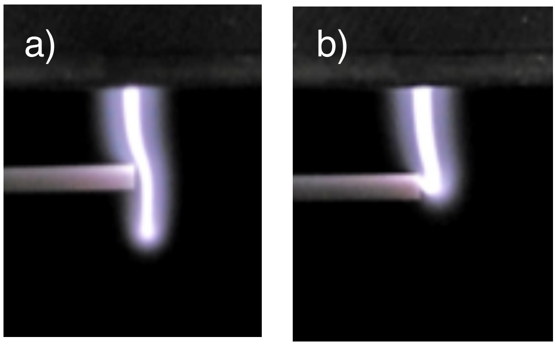

Fig. 4. Comparison of the influence of probe electrodes on the structure of plasma; (a) insulator, (b) metal electrode (single probe)

In addition, fast repetition of transition of the plasma torch which attaches and detaches to a metal probe electrode has been observed. In order to investigate the phenomena during repetition, simultaneous measurements with high-speed camera and an electrical probe have been done. The details are shown in our presentation.

4. Summary

Dynamics of the atmospheric microwave plasma torch have been investigated by using a high-speed camera. It is clarified that propagation of the flame-like structure is related to gas dynamics. Moreover, we have found oscillations of the tip of the plasma torch along the axis-direction. The phenomena would be related to the propagation of microwave as surface wave. With respect to probe measurements, simultaneous measurements with high-speed camera and probe current have been done. Fast repetition of attachment and detachment of the plasma torch to the probe electrode has been observed. These results suggest us an insulated probe method would be effective in avoiding the disturbance.

Acknowledgments

This work was supported by Research Foundation for the Electrotechnology of Chubu, Nagano JRC Co.Ltd. and Shinano-Kenshi Co.Ltd.

References

[1] N. Ezumi, S. Yamada, T. Kobayashi, K. Todoroki et al.: *25th JSPF Annual Meeting, Utsunomiya, Japan, 2- 5 Dec.* (2008), 4aB35P, *in Japanese*.

[2] K. Yanagisawa, S. Iio, N. Ezumi and T. Ikeda: *International Conference on Jets, Wakes and Separated Flows, Cincinnati, Ohio USA,* Sep. 27-30 (2010)

[3] N. Ezumi, N. Kodama, K. Akahane, S. Shiozawa *et al.*: *9th International Workshop on Electrical Probes in Magnetized Plasmas, Iasi, Romania.21-23 Sep.* (2011).