5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Large-Area Ashing Treatment of Polyimide Film by Atmospheric-pressure Pulsed Microwave Line Plasma with Ar/O_2

T. Ogasawara[1], Y. Iwata[1], H. Suzuki[1,2], and H. Toyoda[1,2,3]
[1] Department of Electronics, Nagoya University, [2] Center for Low-temperature Plasma Sciences, Nagoya University, [3] National Institute for Fusion Science
e-mail (speaker): ogasawara.tomohiro@k.mbox.nagoya-u.ac.jp

In recent years, the diversification and demand for electronic devices has been rapidly increasing due to the growing demand for in-vehicle devices, smartphones, PCs, and tablets. As a result, there is a strong demand for device fabrication on large substrates, including resins with low heat resistance, as well as for decrease in manufacturing costs and increase in throughput. Therefore, the application of non-thermal equilibrium atmospheric-pressure plasma, which does not require vacuum systems, to large-area surface treatment is attracting attention, and a large-scale plasma source with high uniformity and high radical density is required. So far, we have developed a method to generate atmospheric-pressure plasma in a one-meter-long slot on the waveguide wall by controlling the propagation direction of electromagnetic waves in the waveguide to one direction and have succeeded in producing a uniform electromagnetic field distribution in the waveguide. Furthermore, by making the cross-section of the waveguide asymmetric to enhance the electric field in the slot, and we succeeded in generating long plasmas containing molecular gases, which had been difficult so far [1]. Spatial uniformity of plasma generation has been also confirmed in this plasma source [2].

In this study, to demonstrate the large-area surface treatment using this uniform long microwave plasma, ashing treatment of polyimide (PI) film by oxygen-doped argon plasma was carried out.

A schematic diagram of the experimental setup is shown in Fig. 1. A loop-structured waveguide and a circulator are used to suppress standing wave for long-scale line plasma production. A long slot is cut on the asymmetric waveguide, which structure is optimized by using electromagnetic simulation to enhance electric field inside the slot. Argon gas (28 slm) and oxygen (0.84 slm) are introduced into the waveguide through a gas manifold on the side of the waveguide wall. Both ends of the waveguide are gas-sealed by airtight windows. The device is cooled by water to control deformation due to thermal expansion. Plasma is generated inside the slot by applying microwave power at a frequency of 2.45 GHz (peak power 3.5 kW, pulse frequency 15 kHz, duty ratio 30%). PI film sample (200 μm in thickness, 30 × 2.5 cm) is placed in the longitudinal direction of the waveguide on a movable glass stage and is exposed to the plasma. After the treatment, ashing depth of the sample is evaluated by a step profiler and ashing rate is obtained from treatment time and ashing depth.

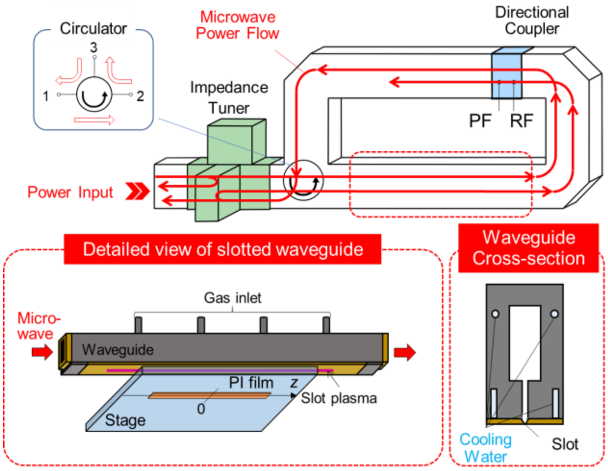

Figure 1. Experimental setup.

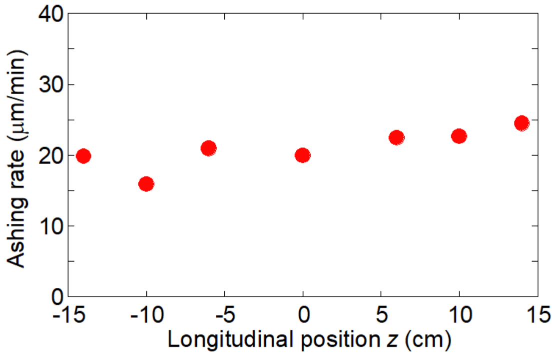

Figure 2. Spatial profile of ashing rate.

Figure 2 shows the spatial profile of the ashing rate along the slot direction. The distance between the slot and the film is 0.5 mm, and the sample sweep speed is 3.0 m/min. The ashing rate is about 20 μm/min and is almost uniform along the slot. This result suggests that large amount of reactive species such as oxygen atoms are uniformly supplied to the surface over a long length of ~30 cm to contribute to the uniform etching of resin film.

Acknowledgement

This work was supported by JSPS KAKENHI JP18K13531.

References

[1] H. Suzuki, et al., Jpn. J. Appl. Phys. **59** (2020) 016002.
[2] H. Suzuki, et al., Plasma and Fusion Research, **16** (2021) 1406046.