Low Temperature Treatment using Atmospheric-Pressure Microwave Line Plasma

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1. Introduction

Atmospheric pressure (AP) plasmas have been given much attention because of its cost benefit and a variety of possibilities for industrial applications such as low temperature and large area processing. We have proposed a newly-developed AP microwave plasma source that utilizes not standing wave but travelling wave. By using this plasma source, it has been demonstrated that spatially-uniform one-dimensional AP line plasma with 40 cm in length can be realized with pure helium gas.[1] The gas temperature was estimated from N_2 second positive band spectra and was low as 400 K and was relatively low compared with other microwave plasma sources.[2] In this study, hydrophilic treatment of PET film is performed as an example of low temperature processes.

2. Experimental

In the experiment, a loop-waveguide antenna consists of a loop-structured waveguide and a microwave circulator. A pulse-modulated 2.45 GHz microwave source (pulse-frequency: 20-80 kHz, duty cycle: 60%, peak power: 2.0 kW) is connected to the circulator through an EH tuner. A section of the loop waveguide with a long slot (60 cm in length, 0.1 mm in width, 1.0 mm in thickness) is vacuum-sealed by two airtight windows and is connected to a vacuum chamber evacuated by a rotary pump to confirm gas purity during the experiment. After the evacuation, mixture gas of helium and nitrogen (1%) is introduced to the gap of the slot antenna through small holes on the waveguide wall facing the slot at total flow rates of 5.0 slm filling the chamber and the waveguide with the mixture gas at a pressure of 100 kPa (atmospheric pressure) monitored by a pressure sensor. AP microwave line plasma is produced inside the slot gap by applying the microwave power. PET film is set at the front of the antenna and the distance between the antenna and the substrate is 2 mm.

3. Results and Discussions

"Real" line[1] and continuous plasma of over 40 cm was generated by mixture gas discharge of helium and nitrogen as well as pure helium discharge. Figure 1 shows the water contact angle at the center of the slot as a function of the treatment time with a fixed pulse-frequency and a duty cycle of 20 kHz and 60%, respectively. The contact angle rapidly decreased down to ~30 degree within 5 s of the treatment time. It should be also mentioned that there was no thermal damage on the substrate.

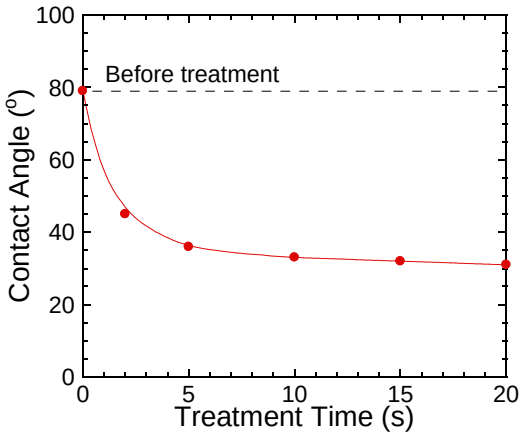

Fig.1. The water contact angle as a function of the treatment time.

Reference

[1] H Suzuki. et al.: Appl. Phys. Express 8 (2015) 036001.
[2] H Suzuki. et al.: submitted to Jpn. J. Appl. Phys.

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