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Photo-Resister Ashing with a Plate to Plate Dielectric Barrier Discharge

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1. Introduction

An atmospheric-pressure dielectric-barrier discharge (AP-DBD) has a non-thermal behavior even at an atmospheric pressure and the reactor may not require expensive high vacuum components [1]. Departure from the thermal equilibrium is one of the main parameters, which are important for the effective surface treatment. The plasma density, stability and uniformity are also important parameters. These days, atmospheric pressure plasmas are being investigated for applications to main flat panel display processing, photo-resist ashing and etching, for the deposition of organic and inorganic materials for diffusion barriers, etc., and to the wet cleaning processing [2].

The number of photo-resist masking steps has increased recently to more than 30 in some new processes, and stripping of the photo resist mask should eventually be done after any photolithograph process. A dry technique of photo-resist stripping is carried out by oxygen plasma, and this is usually called ashing [3].

2. Experimental Set-up

Electrode that is used in this experiment was fabricated with 1mm thick alumina coating. The shape of the electrode is shown in Fig. 1 and dimension of a dielectric material that is coated by screen printing method is 300×100×1mm.

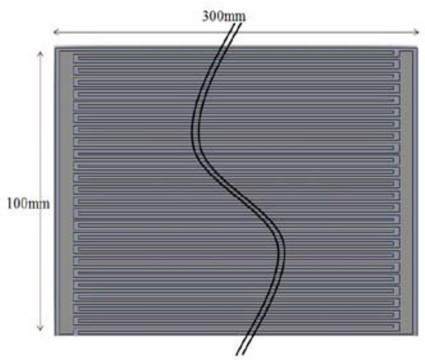

Fig. 1. Type of dielectric material and electrode.

To evaluate characteristics of DBD plasma, we constructed experimental setup as Fig. 2. We used an AC power source that has a range of 0-300V. Tektronix P6015A high voltage probe is used for observing different voltage and current when the parameter was changed like frequency and reactive gas. Agilent 54621A is the oscilloscope for detecting the output signal and measuring the power. To measure the spectrum of DBD, 7344-0001 CCD camera was used made by PRINCETON INSTURUMENT COMPANY.

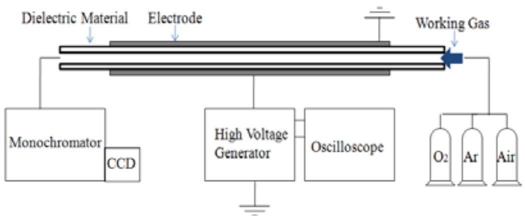

Fig. 2 Diagram of DBD atmospheric plasma equipment.

3. Results and Discussion

A relation between the discharge voltage and current has been shown in Fig. 3. Frequency 1 kHz and electrode distance 3mm is the experimental condition. When the voltage is increased, wall electric charge of the insulator was charged. Later, intensity of electric fields between electrodes has been increased, which ultimately caused an electric breakdown.

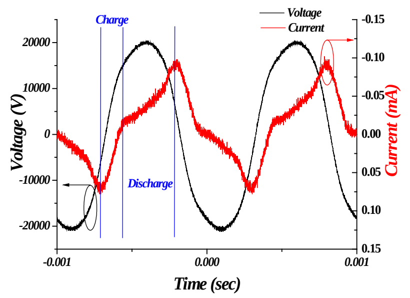

Fig. 3. Voltage and current curves with a time.

Gas temperature of atmospheric plasma is an important parameter and has a correlation with rotational temperature of molecules. Especially, OH, N_2+, O_2 molecular spectrum is possible to measure and calculate the rotational temperature. In this study, first we measured negative system of mono-positive ion (N_2+) of Nitrogen and defined a rotational temperature compared to the theoretical spectrum. Eq. (1) is shown as a theoretical spectrum intensity of di-atomic molecules.

$$I = D_0\, k^4\, S\, exp\left(-\frac{E_r}{k_B T_{rot}}\right) \qquad (1)$$

Where, k is a wave-number, S is an oscillator strength, k_B is Boltzmann constant, E_r is a rotational energy level, and D_0 is a coefficient that is presented by rotational partition function. E_r and D_0 are possible to show by Eq. (2) and (3)

$$D_0 = \frac{C(J'+J''+1)}{Q_r} \tag{2}$$

$$E_r = B_v\, hc\, J'(J''+1) \tag{3}$$

Where, c is constant that is depended on the dipole moment and initial vibration state, Q_r is a rotational partition function, J' *and* J'' is a rotational quantum number of upper state and lower state, B_v rotational constant.

To compare the measurements and theoretical spectrum, line broadening of intensity profile was considered. Eq. (4) showed a convolution calculation that broadening is Gaussian type.

$$\mathrm{I} = \frac{\mathrm{I}_0}{\Delta_i\sqrt{\pi/2}}\ \exp(-\frac{2(\lambda-\lambda_0)2}{\Delta_i^2}) \tag{4}$$

Where, I0 is a spectrum intensity from Eq. (4), Δ_i is a full width at half maximum (FWHM) of instrumental broadening.

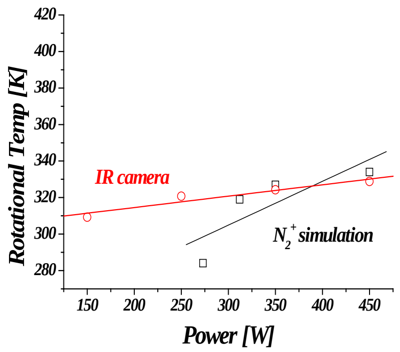

Fig. 4. Rotational temperature used by N_2^+ spectrum.

The Spectrum intensity was measured by CCD camera (7344-0001) made by Princeton Instruments connected with a mono-chromator. FWHM was obtained by comparing the intensity of instrumental broadening and Gaussian fitting value used by He-Ne laser [4]. Instrumental broadening (Δ_i) is 0.2 nm. Fig. 4 showed measurements of rotational temperature about variable power.

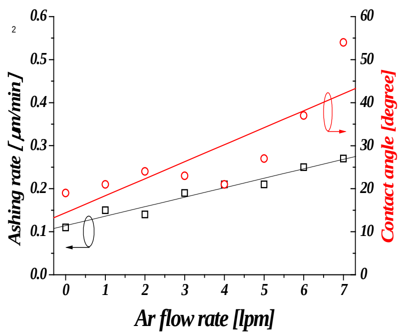

Fig. 5 Contact angle after photo-resist treatment with Ar flow rate. (1kHz, Air : 40 lpm, t : 5 min)

Fig. 5 has shown the ashing rate and contact angle of PR, which has been increased a little by the argon flow rate. In Fig. 6, we can show the PR ashing rate when the Air is fixed at 40 lpm and Oxygen is changed from 0 to 14 lpm. Generally, the increase of an Oxygen compound will increase the ashing rate. The reason is plasma density will decrease if the density of Oxygen is more than 18% & due to the increase of quenching of the Penning ionization [5, 6]. This phenomenon is also shown in Fig. 6.

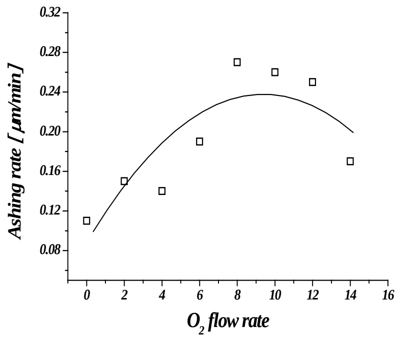

Fig. 6 Photo-resist ashing rates with O_2 flow rates (1 kHz, Air: 40 lpm, Ar: 2 lpm).

4. Conclusions

In this experiment, we make DBD instrument to remote type for the large surface processing. It was operated in atmospheric pressure and make cold plasma where gas temperature was 320K. We observed change of power and energy using the voltage and current dependence using different frequency without air flow.

1 kHz is the most suitable frequency applied, we measure the contact angle of water with PM, Si wafer and glass under the several gas flow. In the PR, we can show that the ashing was occurred to be rough by using the result of contact angle. Another experiment, ashing rate depends on the oxygen concentration. The maximum ashing rate was detected at 1 kHz, air 40 lpm, argon 7 lpm and oxygen from 0.3μm/min to 8 lpm.

REFERENCES

[1] Gon-Ho Kim and Sang-Heon Song, J. Korean Phys. Soc. **49**, 558 (2006).
[2] Yong-Hyuk Lee and Geun-Young Yeom, J. Korean Phys. Soc. **47**, 74 (2005).
[3] Se-Geun Park, Seung-Kook Yang and Jaeky Yang, J. Korean Phys. Soc. **49**, S732 (2006).
[4] S. Y. Moon and W. Choe, Spectrochim. Acta B 58, 249 (2003).
[5] M. A. Lieberman, "principles of plasma discharges and materials processing", John Wiley & Sons, Inc., New York, 217-264 (1999)
[6] A. Grill, "Cold plasma in materials Fabrication", IEEE Press, 46- 61 (1994)