# Basic study of surface treatment at low discharge voltage by atmospheric microplasma

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## 1.Introduction

PEN (polyethylene naphthalate) is a polymer with high thermal and chemical durability, but its surface is not suitable for printing or gluing.

Plasma treatment has been studied to improve the PEN surface characteristics. For industry application, plasma process in atmospheric pressure is desired due to the low cost. Microplasma which is atmospheric pressure non thermal plasma require relatively low discharge voltage. Surface Treatment of PEN film by atmospheric microplasma was investigated.

## 2. Atmospheric microplasma

Atmospheric microplasma is a type of dielectric barrier discharge which has a discharge gap in the order of micro meters. A schematic image of the microplasma electrodes and surface treatment process of PEN film is presented in Fig.1.

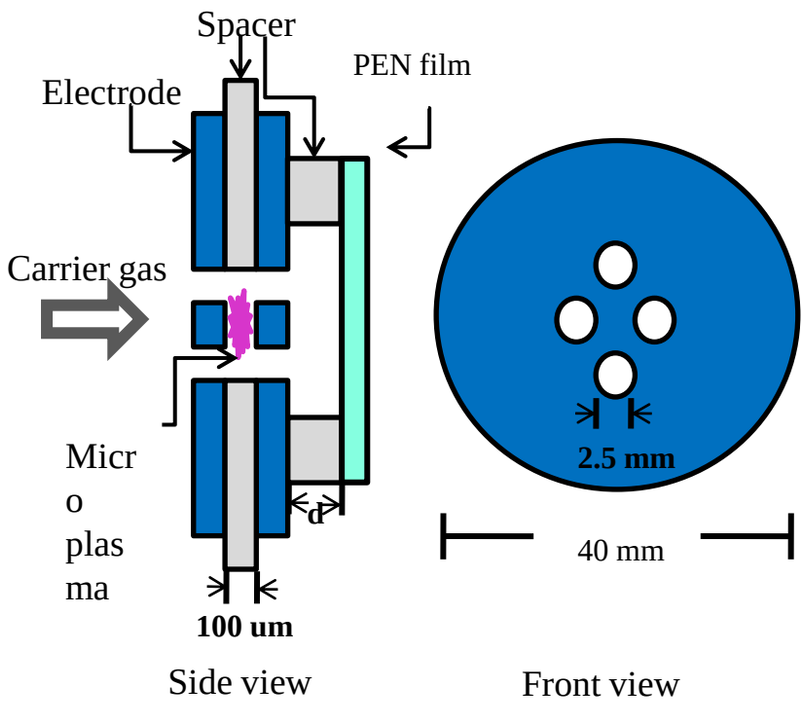



Fig.1 A Schematic image of microplasma electrodes and surface treatment process of PEN film.

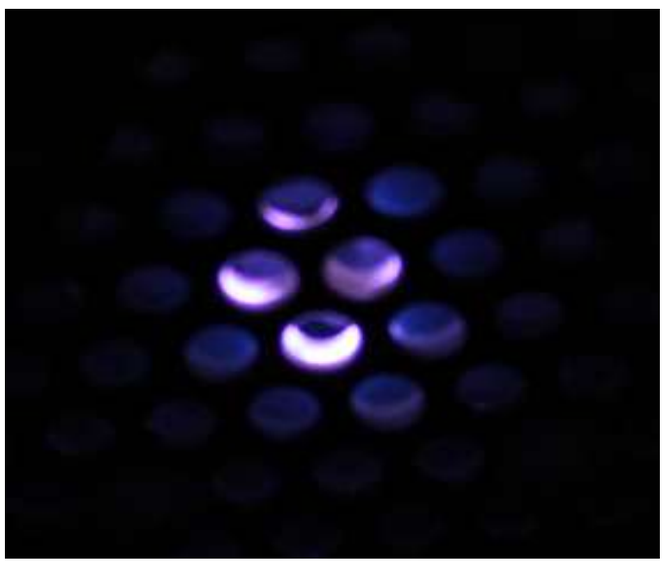


Fig.2 Image of microplasma during discharge.

Two metal circular plates covered with dielectric materials are faced together with a spacer (thickness 100 um) in between. By applying an alternative voltage, streamers generate to form glow-like plasma (Fig.2).

## 3. Experimental setup

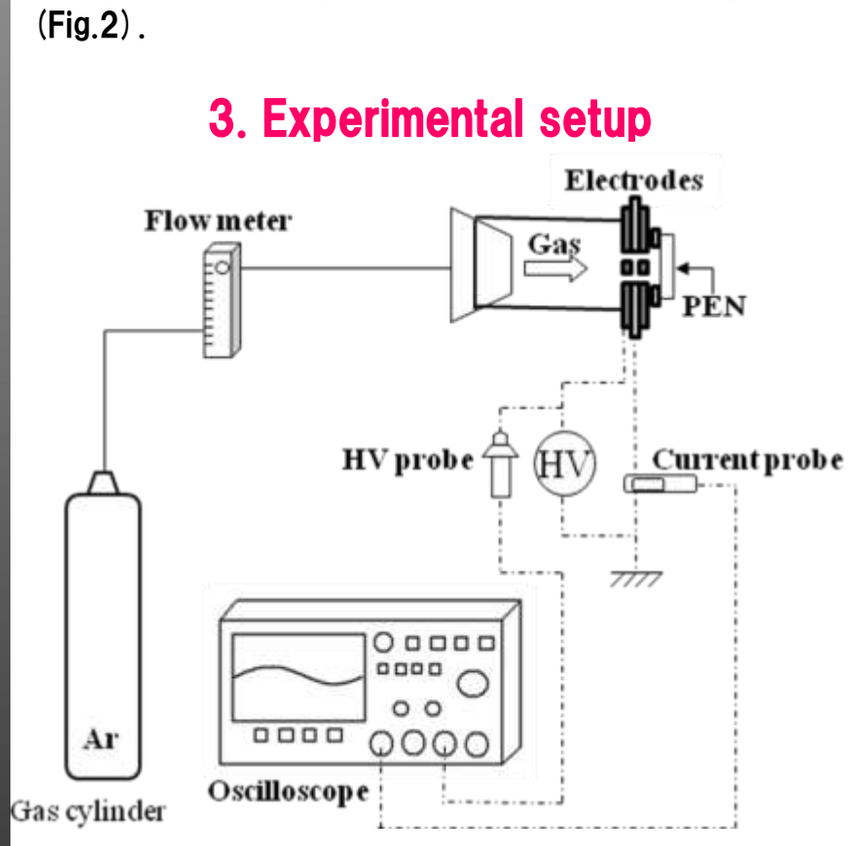


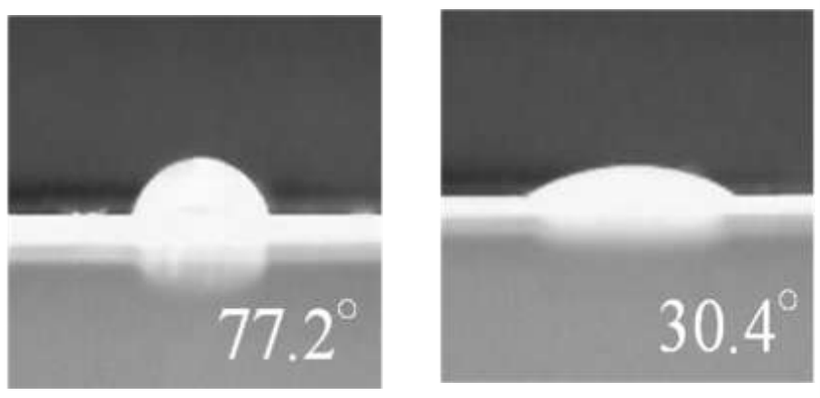

Fig.3 An Experimental setup

Fig.3 shows the experimental setup. Argon gas supplied by a gas cylinder. A neon transformer was used as the power source for microplasma. Innumberable streamers were generated between the electrodes, which generate various radicals. In series of experiments those active species could affect a target surface.

## 4. Results and discussion

### 4.1 Changes in surface hydrophilic property

Surface hydrophilic property was evaluated by measuring static contact angle with a drop of distilled water on the sample PEN film surface.




(a) Before treatment (b) After treatment

Fig.4 Images of contact angle of a waterdrop on PEN film.

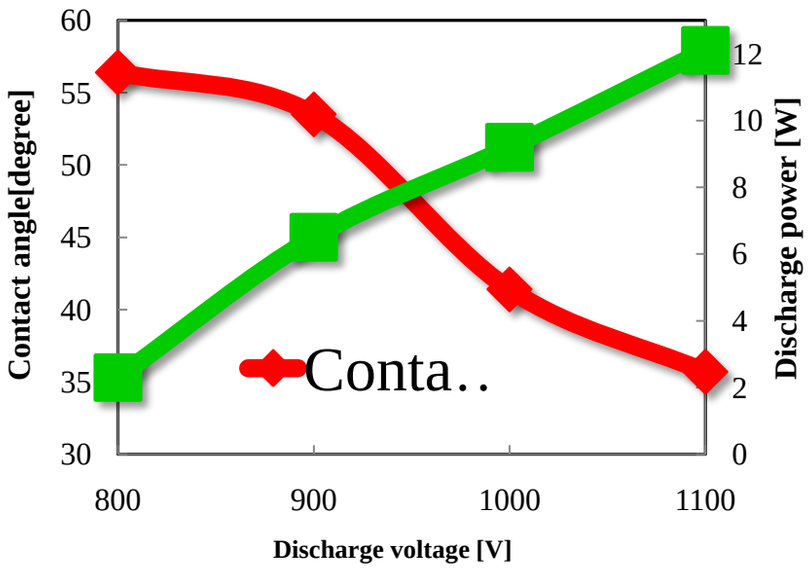



Fig.5 Discharge voltage versus discharge power and contact angle.
(Treatment time 5sec, distance between electrodes and PEN film1 mm, gas flow rate 5 L/min)

Fig.5 shows characteristics between discharge voltage and contact angle. Decrease of contact angle was observed with the increase of discharge voltage.

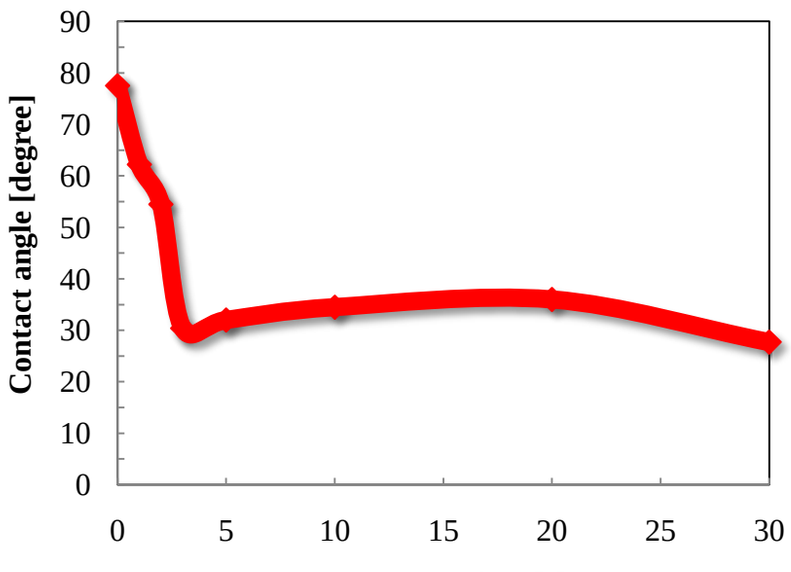



Fig.6 Relationship between treatment time and contact angle.
(Discharge voltage 1.1 kV, distance between electrodes and PEN film1 mm, gas flow rate 5 L/min)

Fig.6 shows characteristics between treatment time and contact angle. Initial contact angle of PEN film was about 80°. The minimum contact angle of about 30° was obtained at treatment time of 3 sec.

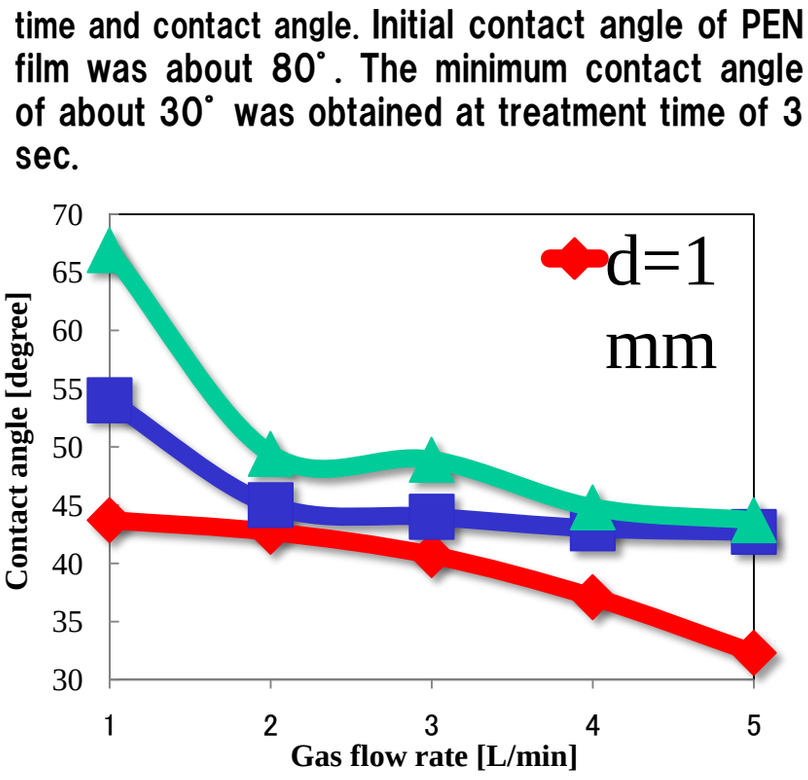



Fig.7 Relationship between gas flow rate and contact angle.
(Treatment time 5sec, discharge voltage 1.1 kV)

Fig.7 shows caracteristics between gas flow rate and contact angle. Decrease of contact angle was observed with increase of gas flow rate. When the distance between electrodes and PEN film was shorter, contact angle tended to be smaller.

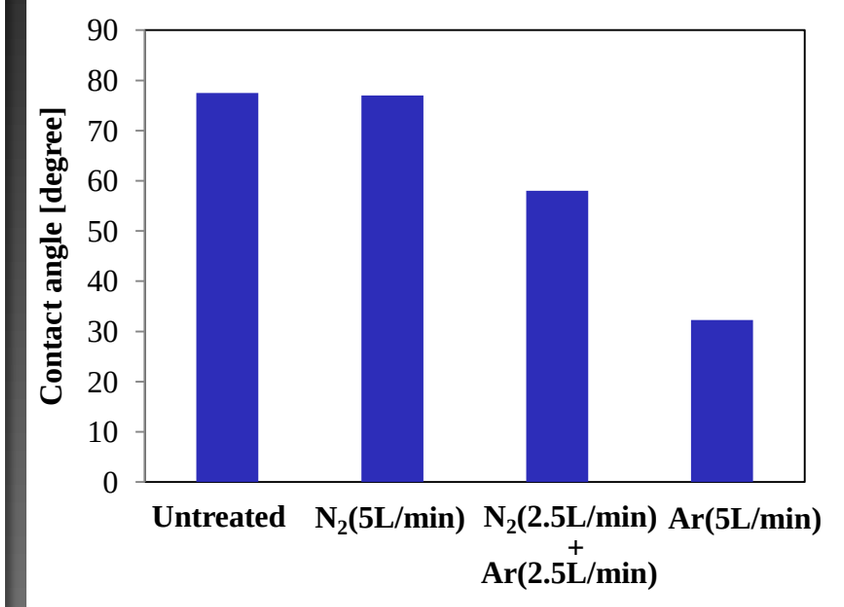



Fig.8 Effect of treating gas for the contact angle on sample surface.
(Treatment time 10sec, discharge voltage 1.2 kV, d=1 mm)

Fig.8 shows the effect of gas on surface treatment of PEN film. Contact angle was not decreased when only nitrogen was used as treating gas. Addition of argon affected the PEN film surface and as a consequence the contact angle decreased.

### 4.2 XPS analysis

X-ray photoelectron spectrometer (XPS) was used to analyze chemical changes of the sample surface.

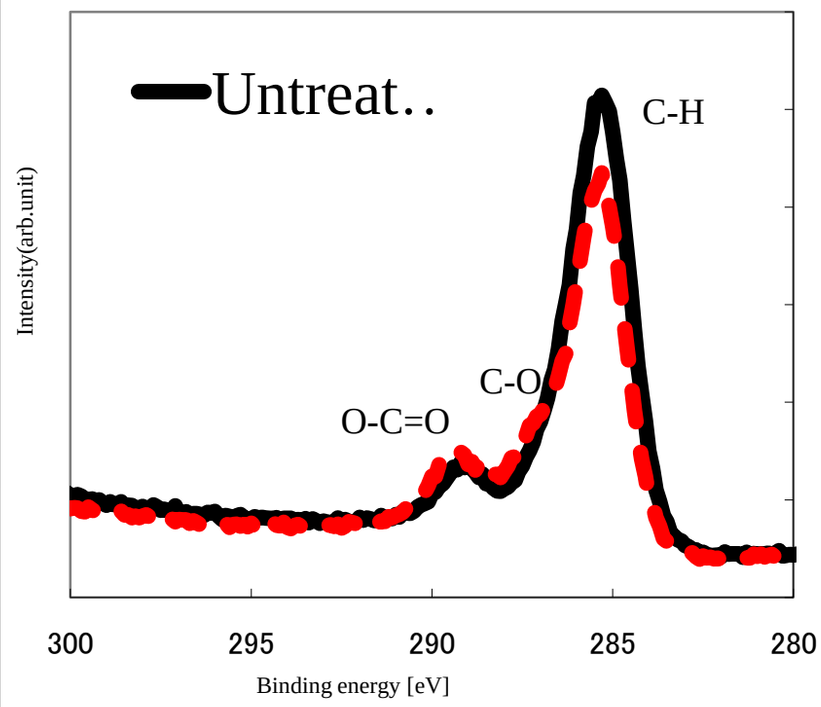



Fig.9 XPS C1s peaks of PEN films.

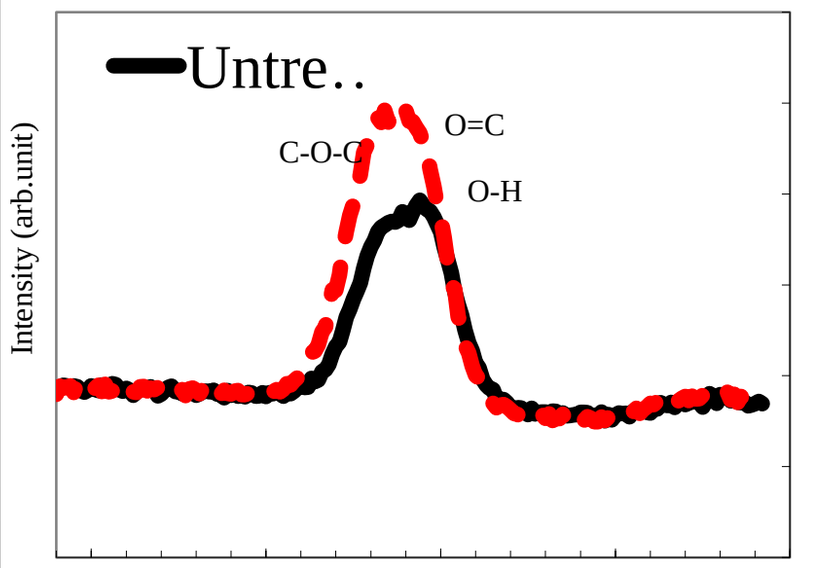



Fig.10 XPS O1s peaks of PEN films.

Fig.9 and Fig.10 show that decrease of C-H bond and increase of C-O-C bond , O=C bond and O-H bond. Decreasing of C-H bond that is hydrophobic functional group was one factor of improving hydrophilic property of surface of PEN film.

## 5. Conclusions

The following conclusions were obtained by the series of experiments.

(1) Surface of PEN film was modified by atmospheric microplasma at a discharge voltage of 1.1 kV .

(2) The minimum contact angle of about 30° was obtained at treatment time 3 sec with Ar.

(3) Surface of PEN film was chemically modified by atmospheric microplasma.

(4) Physical deformation by heat was not confirmed by microplasma surface treatment, since its discharge voltage was very low.