Study on Surface Modification of PEN Film by Remote Ar Microplasma

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1. Introduction

Polymer materials have a wide field of application for example in food industry, medical equipments, electronic, in information technology industry, etc. Plasma treatment has been studied to improve the PEN (polyethylene naphthalate) surface characteristics. For industry application, plasma process in atmospheric pressure is desired to minimize the cost and process time. Microplasma which is atmospheric pressure non thermal 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 miroplasma electrodes (hole size of 1.1 mm) and surface treatment process of PEN film is presented in Fig.1.

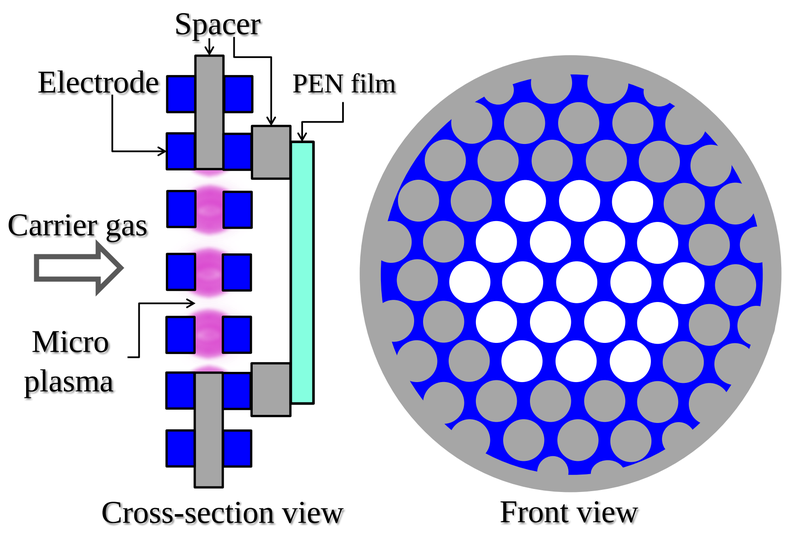


Fig.1 A Schematic image of microplasma electrodes and surface treatment process of PEN film.

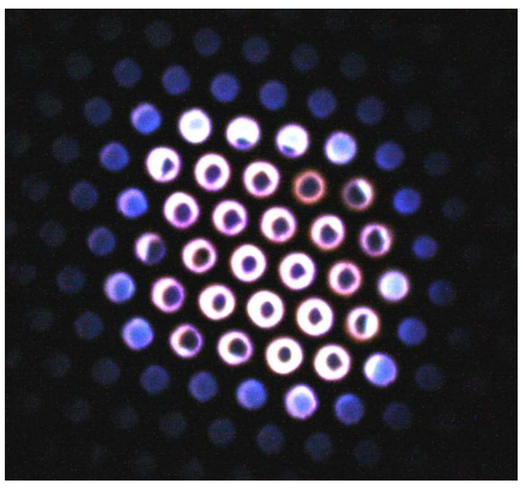


Fig.2 Image of microplasma during discharge.

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

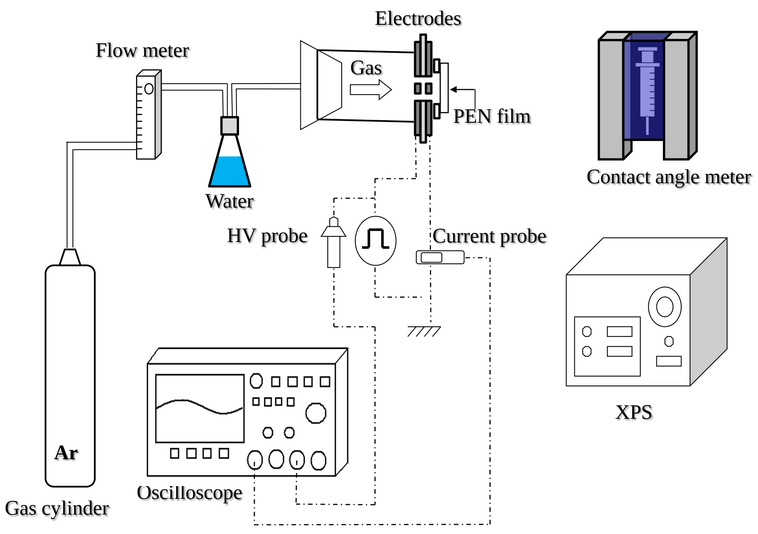


Fig.3 An Experimental setup

Fig.3 shows the experimental setup. Argon gas was supplied by a gas cylinder. Argon gas had some humidity due to water inside flask. We used a Marx generator which generates negative pulsed for generating microplasma. Innumerable streamers were generated between the electrodes, which generate various radicals. In series of experiments those active species could affect a target surface.

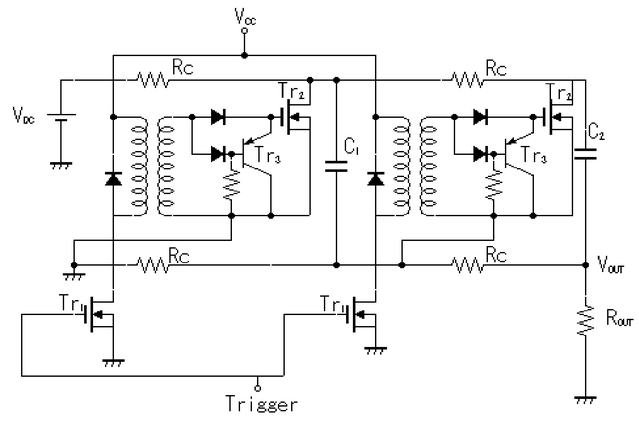


Fig.4 An example of Marx generator circuit.

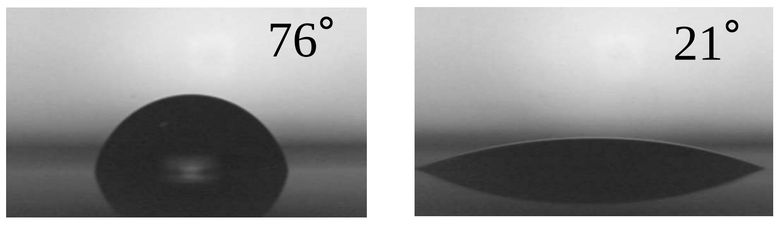
Fig. 4 shows an example of Marx generator circuit. When the switches (Tr_2) are opened, the capacitors linked in parallel connection are charged at a given voltage *E*.

By turning on the switches, the capacitors discharge in series connection. The voltage will have the value *E* multiplied with the number of capacitors.

4. Results and discussion

4.1 Changes in surface wettability

Surface wettability 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.5 Images of contact angle of a waterdrop on PEN film.

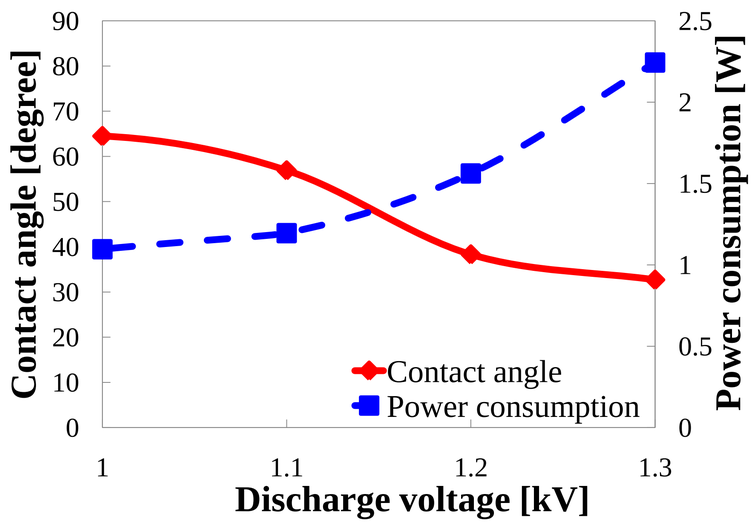


Fig.6 Discharge voltage versus discharge power and contact angle.

(Treatment time 5sec, distance between electrodes and PEN film1 mm, gas flow rate 5 L/min, gas humidity 0 %RH)

Fig.6 shows characteristics between discharge voltage and contact angle. Decrease of contact angle was observed with the increase of discharge voltage.

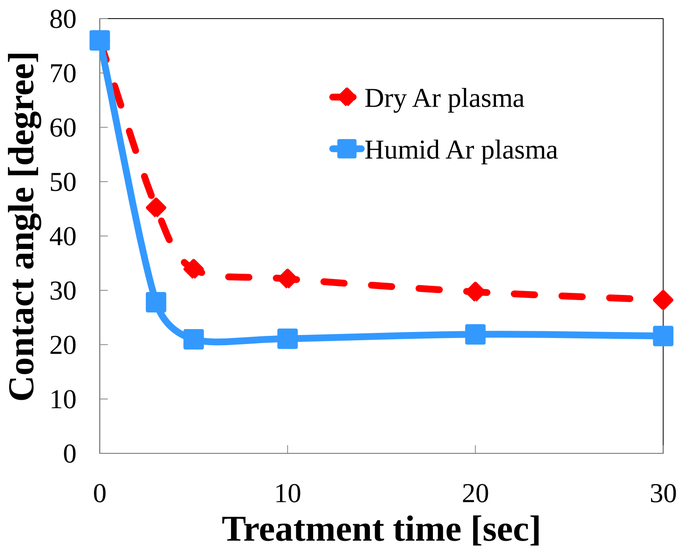


Fig.7 Relationship between treatment time and contact angle.

(Discharge voltage -1.3 kV, distance between electrodes and PEN film1 mm, gas flow rate 5 L/min, gas humidity 0 %RH and 63 %RH)

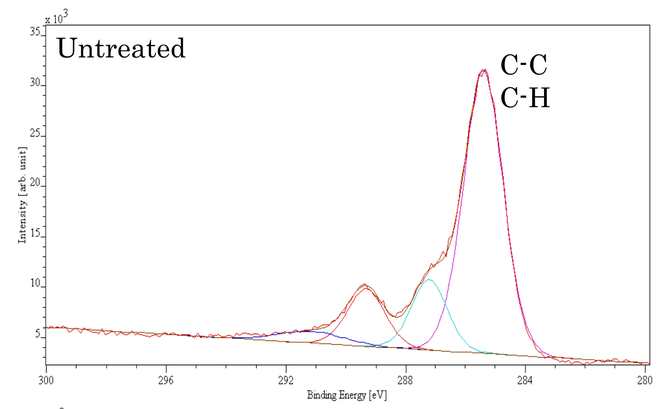
Fig.7 shows characteristics between treatment time and contact angle. Initial contact angle of PEN film was about 76˚. The minimum contact angle of about 21˚ was obtained by the treatment time of 5 sec and the gas humidity of 63 %RH.

4.2 XPS analysis

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

Table 1 XPS analysis on PEN films.

Sample	Atomic concentration [%]			O/C ratio
	C	O	N	
Untreated	77.95	21.95	0.1	0.28
Treated by humid Ar	69.45	30.16	0.39	0.43



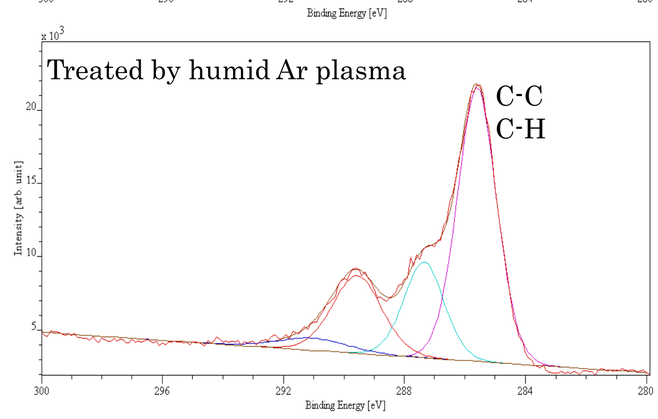
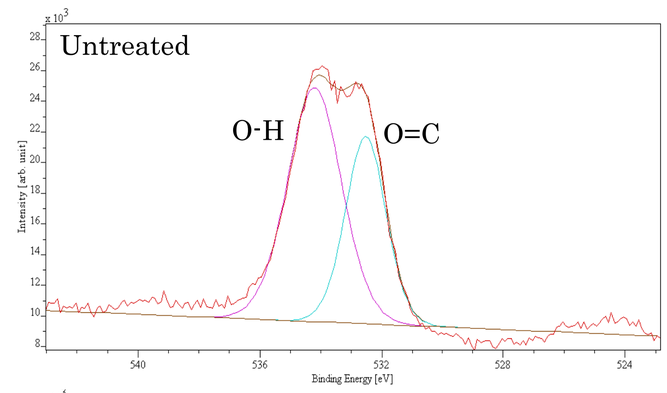


Fig.8 XPS C1s peaks of PEN films.



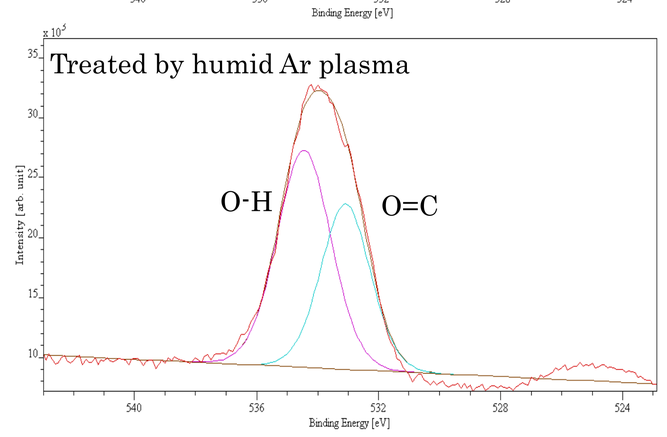


Fig.9 XPS O1s peaks of PEN films.

Fig.8 shows the decrease of C-H bond and C-C bond that are hydrophobic functional group. Fig. 9 shows the increase of O-H bond and O=C bond that are hydrophilic functional group. These changes contributed to improving hydrophilic property of the PEN surface.

This could be the result of the metastable excited argon atoms responsible for attacking the C-H or C-C bond leading to the production of carbon radicals on the PEN surface. Since the carbon radicals could react with oxygen, nitrogen, water vapor in the atmospheric air and carrier gas, hydrophilic functional group increased after plasma treatment.

5. Conclusions

(1) Surface of PEN film was modified by atmospheric microplasma at a discharge voltage of -1.3 kV .

(2) The minimum contact angle of about 21˚ was obtained by the treatment time 5 sec with humid Ar.

(3) It was confirmed that humid Ar plasma was more effective in surface treatment than dry Ar plasma.

(4) Decrease of hydrophobic functional group and increase of hydrophilic functional group were observed after microplasma treatment on the PEN film.