ATMOSPHERIC PRESSURE PEN-LIKE PLASMA TREATMENT OF PE FILM
XỬ LÝ MÀNG PE BẰNG PLASMA Ở ÁP SUẤT THƯỜNG

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ABSTRACT

In order to improve the printing ability on polyethylene (PE) thin film and enable a simpler plasma treatment technology, PE was treated by high radio frequency atmospheric pressure pen-like plasma (plasma torch). The investigation on the effect of treatment conditions such as power, time and Ar gas flow rate on the contact angle of PE surface was carried out. To compare the effect of atmospheric and low-pressure plasma treatment, PE thin film was also treated by low-pressure plasma system AST at 2 Torr. The results show that both atmospheric pressure as well as low-pressure plasma treatments caused a significant decrease of contact angle, however the effect was higher at the atmospheric plasma treatment. After treatment, the contact angle of PE film to water decreased from 88,7^0 to 43,3 ^{0} at low-pressure and 27,1^0 at atmospheric plasma. The soft ware Sigmaplot 10 was used to optimize the treatment condition of PE thin film at the atmospheric pen-like plasma. The optimal treatment conditions deduced from contour face were 50W, 1 minute and flow rate of 5 l/min, which resulted in a much better printing ability on the treated PE surface.

TÓM TẮT

Để nâng cao khả năng in trên nền màng mỏng polyetylen (PE) và giảm nhẹ các thông số công nghệ, đã nghiên cứu xử lý màng bằng plasma RF pen-like ở áp suất thường và khảo sát ảnh hưởng của cường độ, thời gian va tốc độ dòng chảy khí Ar đến góc tiếp xúc của bề mặt màng với nước. Để so sánh kết quả với phương pháp xử lý plasma ở áp suất thấp, màng PE cũng được xử lý ở áp suất 2 Torr trên hệ thống thiết bị AST. Kết quả cho thấy, cả hai phương pháp xử lý đều làm giảm cơ bản góc tiếp xúc. Tuy nhiên, xử lý plasma ở áp suất thường có hiệu quả cao hơn so với xử lý ở áp suất thấp. Sau khi xử lý, góc tiếp xúc của màng PE với nước giảm từ 88,7^0 xuống 43,3^0 ở áp suất thấp và 27,1^0 ở áp suất thường. Từ các kết quả thu được, đã sử dụng phần mềm Sigmaplot 10 để tính toán điều kiện xử lý tối ưu cho màng PE có góc tiếp xúc thấp nhất. Điều kiện thích hợp để xử lý là 50 W, 1 phút và tốc độ dòng khí 5 l/phút. Khả năng in trên PE đã xử lý plasma được cải thiện rõ rệt

I. INTRODUCTION

The plasma state is often referred to as the fourth state of the mater. It is a global quasi-neutral system of free positive (and some times also negative) ions and negatively charged electrons in a neutral background gas containing atoms, molecules and free radicals. Plasma is generally created by supplying a sufficient amount of energy to a volume containing a neutral gas, so that free electrons and ions are generated from atoms and molecules in the gas. The energy may be supplied in the form of electrical energy, heat, ultra violet radiation or particle beam etc. Among two main kinds of plasma with very different applications: thermal, equilibrium plasma (the electron, ions and neutral gas temperature are roughly equal) and non-thermal, non-equilibrium plasma (the electron temperature much larger than the ion temperature and the neutral gas temperature), the non-thermal, non-equilibrium plasma (cold plasma) has been applied successfully for surface treatment [1,2].

Polymeric materials, such as polyethylene (PE), have excellent bulk physical and chemical properties, are inexpensive, easy to process and therefore have been widely used in fields such as adhesion, biomaterials, protective coating, composite, microelectronic devices and thin-film technology. In general, special surface properties with regard to chemical composition, hydrophilicity, roughness, crystallinity, conductivity, lubricity etc. are required for success of these applications. Polymers very often do not possess the surface properties needed for these applications. PE for example is hydrophobic material. This characteristic causes difficulty

in printing or coating on the polymeric surfaces. Traditionally, the polymeric surface was modified by chemical method to make it more hydrophilic. Chemical methods are wet methods and therefore are eco-unfriendly due to the waist solution and emitting volatile organic chemicals. Recently, plasma treatment has become an important industrial process for modifying polymer surface. As a dry and clean process, the plasma treatment is considered as a potential effective and environmental friendly method to get a better wettability and to form more suitable surface morphology for coating and printing.

Most previous research related to low-pressure plasma for surface modification [2,3]. However, in the treatment of PE film, to initiate and maintain plasma discharge requires expensive vacuum system and productivity is low. To avoid these drawbacks, atmospheric pressure plasma discharge has been proposed and created.

In this study, high radio frequency plasma discharge was used to modify the surface of PE film to enhance the surface property for coating and printing purpose.

II. EXPERIMENTAL

The PE films were treated with atmospheric and low-pressure plasma system.

Radio frequency (RF) used to produce plasma is of standard 13.56 MHz. Experiments were carried out in atmospheric conditions of the pen-like plasma with power 50-90W, time 15s-180s; argon gas flow rate 5-20 l/min and in low pressure conditions of plasma system AST with power of 60W, pressure 2 Torr; flow rate 0.1 l/min; time 30s-20min; argon gas.

Fig.1 is a self-installed RF plasma torch (pen-like plasma) used to treat PE film at atmospheric pressure. For low-pressure plasma treatment a RF low-pressure system AST was used as showed in Fig.2.

The surface properties of PE film were evaluated by Contact angle FACE CA-VP.

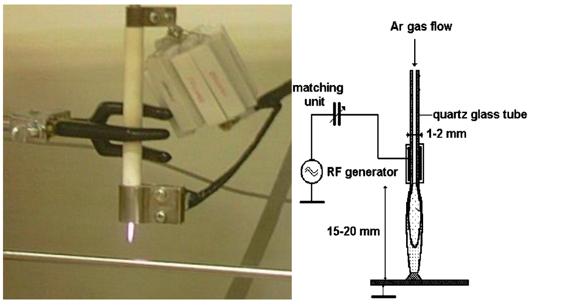


Fig.1 Self-created plasma torch (pen-like) device

Fig. 2 Low pressure plasma system AST

The contour face to optimize the treatment conditions was created using software Sigmaplot 10.

III. RESULTS AND DISCUSSION

Effect of power

One of the most important factors in plasma treatment indicating the intensity of plasma is power. Fig.3 shows the result on influence of power on contact angle of PE film.

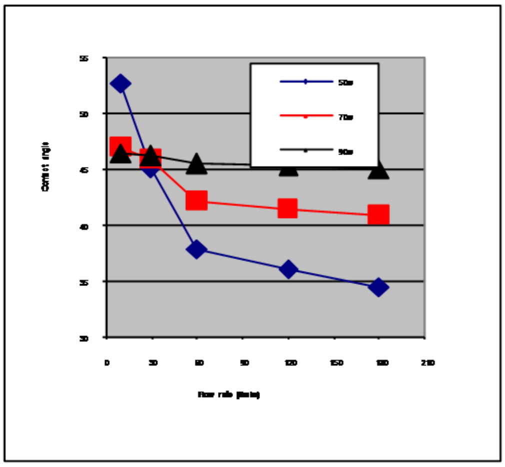


Fig.3 Effect of power and flow rate on the contact angle

At the power of 50W the contact angle decreased rapidly with increasing flow rate. The lowest contact angle was 34,5^{o} at the flow rate of 180 l/min. At higher power of 70W and 90 W and same flow rate the reducing rate of contact angle is slower and contact angle only reached the value of 40,5° and 45°. The higher power is the slower decrease rate of contact angle is. There is interaction between time and flow rate due to un-parallel curves. The contour face created by using software Sigmaplot 10 for optimum condition at flow rate of 15 l/min in Fig. 4 showed that at the zone of the lowest contact angle (around 30°) the corresponding power should be between 50 to 60 W.

This result is similar to some other research on treatment of polyolefin polymer that the best effect was at the power between 30W and 60 W [4].

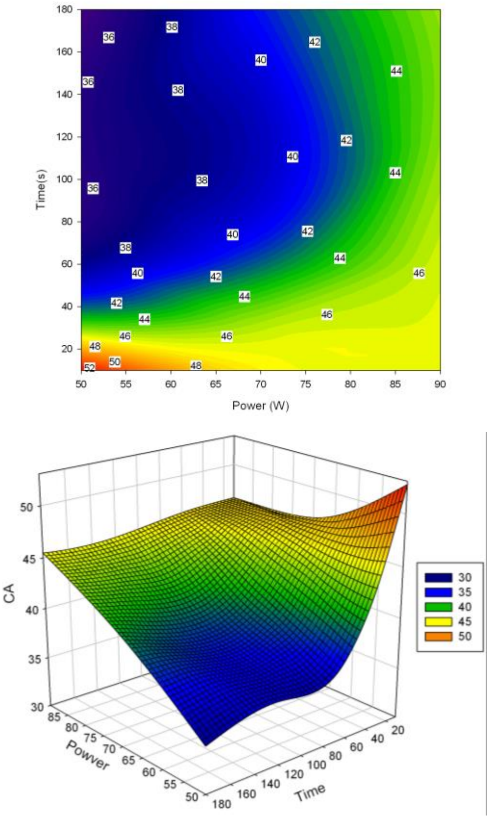


Fig.4 Contour face to optimize power and time

Effect of treatment time and gas flow rate

Fig. 5 showed the effect of treatment time and flow rate of Ar gas on the contact angle of PE film.

It can be seen that at the power of 50W the contact angle was getting lower with decrease of the treatment time and flow rate . At flow rate of 5l/min and 10 l/min the contact angle decreased dramatically and reached 28,5° and 27,1° after 60 s and 180 s, respectively. There is no interaction between time and flow rate, indicated by nearly parallel curves.

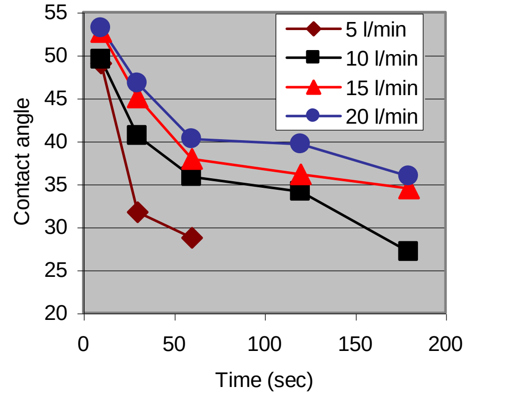


Fig.5 Effect of treatment time and Ar gas flow rate on the contact angle

Fig. 6 is the contour face created at power of 50W. From the zone corresponding the lowest contact angle (around 25-30°) the optimum treatment condition for PE film was deduced: at power 50W, time 60s and flow rate 5 l/min.

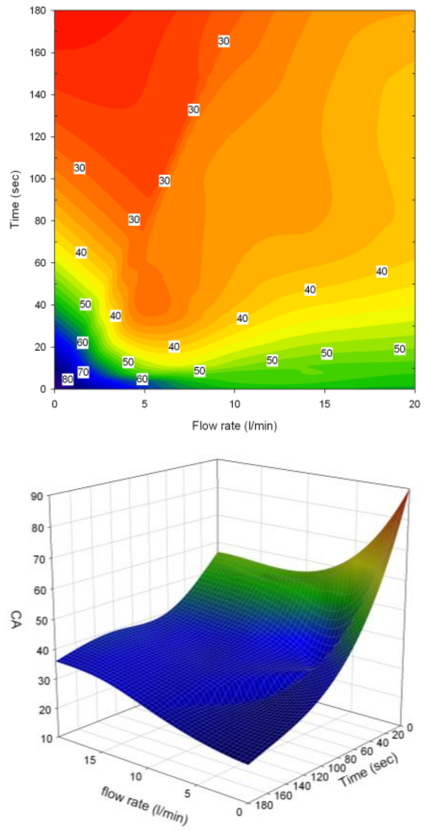
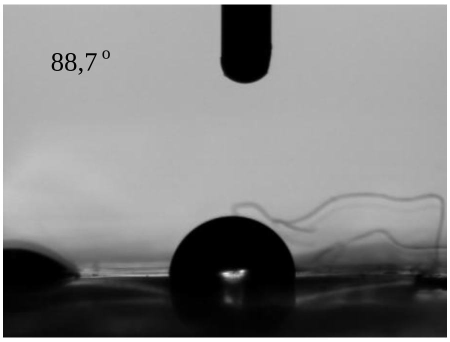


Fig.6 Contour face for optimum conditions of contact angle of PE film

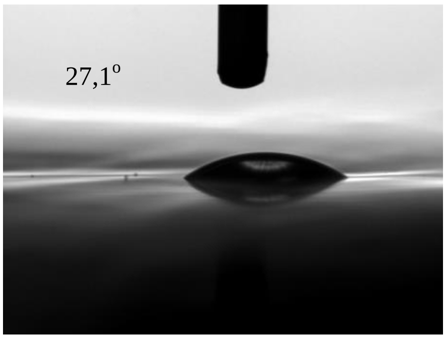
Contact angle

The contact angle of PE film before and after atmospheric pressure and low-pressure plasma treatment are presented in Fig. 7 and Fig.8.

As showed, before treatment the contact angle was high, 88,7^o (Fig.7a), since PE is hydrophobic due to many -CH_3 groups in the PE’s structure. After treatment, the contact angle decreased remarkably, from 88,7^o to 27,1^o (Fig.7b) at atmospheric pressure and 43,3^o at low-pressure plasma (Fig.8).



a. un-treated



b. treated

Fig.7 Contact angle of PE film before and after atmospheric pressure plasma treatment

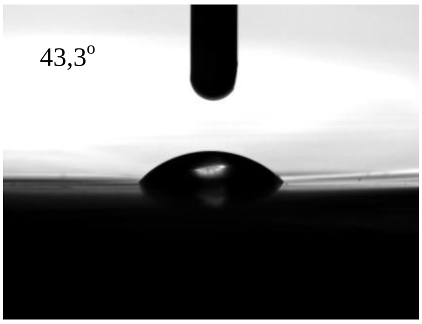


Fig.8 Contact angle of PE film after low-pressure plasma treatment

The plasma treatment might cause the oxidation of –CH_3 groups as well as –CH_2- of PE in to –OH or –COOH groups that made PE surface more hydrophilic and therefore possessed lower contact angle to water. At the atmospheric pressure plasma, the density of charged particles bombarding the PE film surface was higher than that at low-pressure which might lead to higher effect on contact angle, it means lower contact angle (27,1^o vs 43,3^o).

Printing ability

The printing ability on un-treated and pen-like plasma treated PE film was presented in Fig.9.

It can be seen that after cleaning the adhesion of print ink at the atmospheric pressure pen-like plasma treated area B is much better than that at un-treated area A, due to better wettability and adhesion. In addition, the area A (untreated) and B (treated) was very close to each other. It means that the pen-like plasma can be used very convenient, not only for larger area but also for smaller area as needed. It is no need to treat the whole piece of film or large area as at low-pressure or corona plasma treatment.

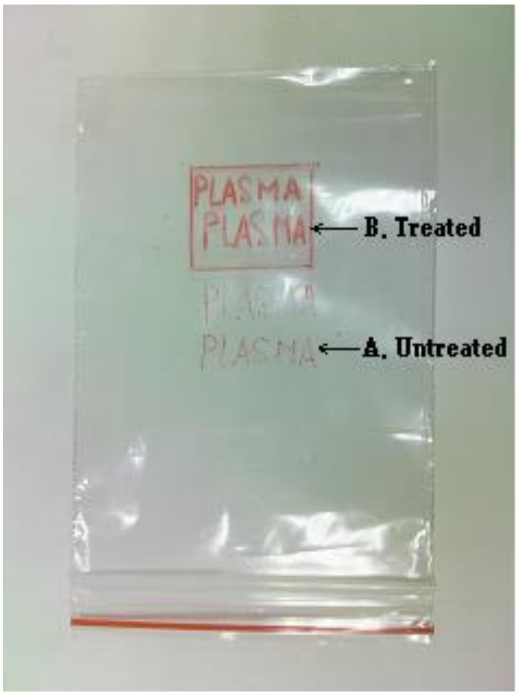


Fig.9 Printing ability on PE film

IV. CONCLUSIONS

RF discharge low-pressure and RF atmospheric pressure plasma torch were used to treat PE film to improve the adhesion of print ink to the film surface. Plasma treatment reduced remarkably the contact angle of PE film surface with water from $88,7^o$ (hydrophobic) to $43,3^o$ and $27,1^o$ (hydrophilic). Especially, the atmospheric pressure plasma torch was more effective for creating low contact angle. The optimum conditions for the plasma treatment of PE film were deduced from contour face: power 50W; time 60s; flow rate 5 l/min. After treatment the printing ability on PE film significantly increased

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