International Journal of Recent Research and Review, Vol. IX, Issue 4, December 2016

ISSN 2277 – 8322

Surface Treatment of Polycarbonate (Pc) by Atmospheric Pressure Dielectric Barrier Discharge (APDBD) Using 50Hz Power Supply

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***Abstract*---Modification of polycarbonate surface is important of various purposes like printing, dying adhesion enhancement etc. In this paper, we report on the surface modification of polycarbonate by cold non- thermal plasma using Atmospheric Pressure Dielectric Barrier Discharge (APDBD) with relatively large electrodes. The surface analysis and characterization are performed using contact angle measurement and weight loss effect the plasma treated polycarbonate exhibit improved surface characteristics. The surface energy of the PC is increased and contact angle is found to be decreased. The weight loss effect confirmed that sputtering and etching processing is occurred after plasma treatment on the PC surface.**

***Keywords* - Contact angle, Surface energy, Etching, Wettability, Hydrophilicity**

I. INTRODUCTION

Polycarbonate, being a versatile material with attractive processing and physical properties has myriad of applications. It is used as an automobile headlight, lamp cover, hind screen, camera and optical lenses etc. But due to low surface energy, poor chemical reactivity and the presence of weak adhesion layer on the surface. Polycarbonates (PCs) are often difficult to wet and offer poor adhesion to their contagious material. So it is necessary to change or improve some of the surface properties without altering its bulk properties. Application of plasma produced by Atmospheric Pressure Dielectric Barrier Discharge (APDBD) is one of the best solutions to improve the surface properties of polycarbonate. In plasma treatment method first, plasma removes bonded impurities from the polymer surface. Secondly, it creates new functional and cross linking groups, usually hydrophilic nature on the surface of the sample [1]. Addition of these functional groups plays a crucial role to increase surface energy of the polycarbonate.

The aim of present work is to increase the surface energy by decreasing the contact angle in cost effective way using the electrode having relatively larger surface area and by decreasing the thickness of dielectric barrier. Measurement of contact angle of liquid with the solid surface permits a rapid and qualitative evaluation of surface free energy of polymers [2]. The contact angle of liquid on solid is closely related to surface free energy and this parameter is useful in the discussion of hydrophilicity, absorbency of sample and adhesivity. Also, high energetic particle of plasma on the polycarbonate surface causes rapid removal of low molecular contaminants and outermost macromolecules. This removing process is called or etching. This process may be due to the physical removal of molecules of fragments or breaking up of bonds, chain scission and degradation process [3]. The plasma treated surface is characterized by contact angle measurement and sputtering/etching rate of polycarbonate.

II. EXPERIMENT

For the production of plasma, a high voltage power supply operating at line frequency 50Hz is used. The power supply is designed by Nepal Engineering Ekarta

Co. Pvt Ltd (NEEK). Discharge was produced from two metallic discs of diameter 10cm and thickness 1cm. A glass plate having thickness 1.12mm was used as barrier on the lower electrode surface. Polycarbonate sample received from GE plastic India, were cut in to size 40mm×8mm×2mm. then the sample were washed for 5 minute in methanol and then washed ultrasonically for 10 minutes with the help of distilled water using ultrasonometer device.

Working gas plays an important role in the production of discharge. We used mixture of air and organ gas for the plasma generation. Generally, inert gas like argon predominantly initiates surface activation by generation of free radicals on the surface by means of chain scission [4].In our work the surface properties of the sample were analyzed by contact angle measurement of sessile liquid drop of 4µl by using rame'- heart goniometer. The surface energy of the sample was characterized by using Owens- Wendt-Kaelble two liquid methods [5].

The sputtering effect is determined by measuring the normalized weight loss after treatment which is easy and reliable method. This method is also called gravimetric method.

Table I

Contact angle and surface energy at different treatment time by using air-argon plasmas at 11.74kV

S.N	Treatment time (Sec)	Contact Angle (degree)	Surface Energy (mJ/m^2)
1	0	88.28 ±1	28.1 ±0.4
2	10	54.08 ±2.1	47.87 ±1.64
3	20	51.37 ±0.06	49.77 ±0.16
4	40	48 ±0.31	52.13 ±0.22
5	60	46.52 ±0.95	53.16 ±0.68
6	120	44.95 ±1.6	54.28 ±1.23
7	300	44.7 ±0.19	54.53 ±0.25
8	600	44.45 ±0.15	54.59 ±0.11

The weight loss rate after normalizing with area can be expressed as:

Normalizing weight loss = $(w_{ut} - w_{pt})/A$

Where, w_{ut}, w_{pt} and A are the weight of untreated sample, plasma treated sample and surface area of the sample respectively. The weight of the sample is measured with the help of micro balance.

III. RESULT AND DISCUSSION

A. Effect of treatment time

Treatment time is one of the important factors to change the wettability of the sample. In our experiment, the contact angle decreased from 88.28° to 54.08° within 10sec of treatment time at 11.74kV. On the other hand, the surface energy increases from 28.1mJ/m^2 to 47.87mJ/m^2 after 10 sec of treatment. After two minutes the decrease in contact angle seem to be nearly same which is very less. And same fact can be seen in surface energy. This indicates that the major fraction of the surface hydrophillization occur only during the first minute of treatment. This may be due to the fact that the plasma can affect the top most layer of the polymer only. Also, at initial phase plasma species breaks the bond between carbon of polycarbonate and after some time the carbon bond get saturated.

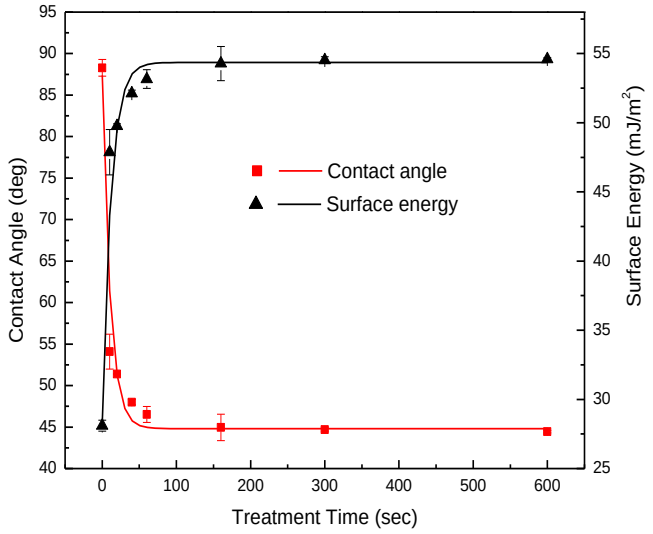

Fig. 1. Contact angle and surface energy as a function of the treatment time at 11.71Kv

B. Effect of applied voltage

Applied voltage is another major factor which determines the discharge characteristics. So its effect can be seen on the modified surface of the material by the discharge. In 10sec of treatmentthe contact angle was found to be decreased from 88.28° to 65.5° in 9.39kV and 51.37° in 11.74kV.

After 600 sec of treatment, it reduced to 53.24°, 44.25° and 44.16° with an applied power of 9.39kV, 11.74kV and 14.09kV respectively. Also, surface energy of untreated sample is 28.1mJ/m^2. After 10 sec of treatment it reached to 40.14mJ/m^2 and 47.78mJ/m^2 with an applied power of 9.39kV and 11.74kV respectively. It can be noted that on the same treatment time, surface energy of sample increases more with the greater value of applied voltage. This is because, plasma species on greater value of applied voltage gain more kinetic energy and hence probability of striking the sample surface by the plasma species is high.

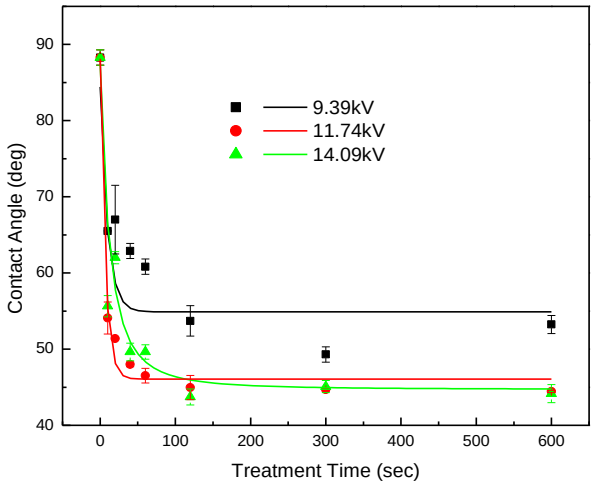

Fig. 2. Variation of contact angle with treatment time at different applied voltages

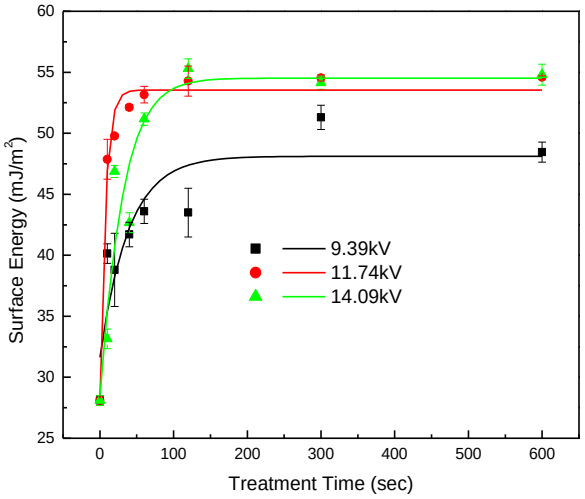

Fig. 3. Variation of surface energy with treatment time at different applied voltage

C. Sputtering/Etching effect

Etching/ sputtering effect is determined by measuring normalized weight loss after treatment which is easy and reliable methods. This method is also called gravimetric method. We have found that normalized weight loss increases as the exposure time is increase. Plasma contains highly energetic particles by which the lower molecular contaminants and outer most macromolecules of the material. This is the main cause of loss in weight. But after 5minute of exposure time significant increase in weight loss cannot be seen. This is because at the beginning there was removal of the surface contamination as well as the material, while after few minutes the removal was of the outermost macromolecules of material. Also, it may be due the fact that there is equilibrium between removal and deposition of the component of the material.

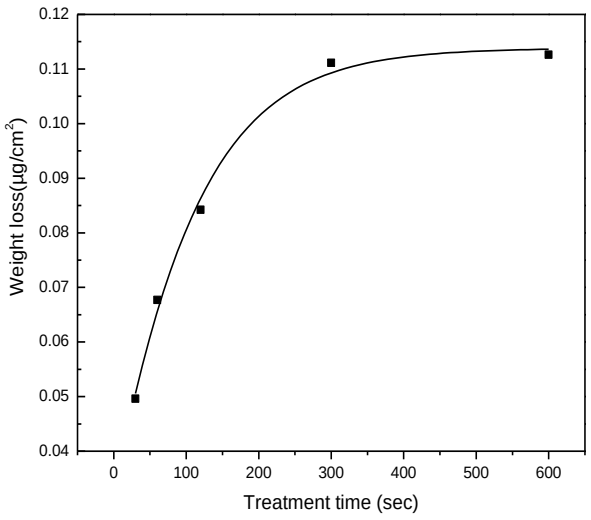

Fig. 4. Normalized Weigh Loss as function of treatment time at 11.74kV

IV. CONCLUSION

In our experiment, electrodes of larger surface area were used as compared to the previous work conducted in our lab. It has been found that larger electrodes also produce uniform discharge by decreasing the thickness of the dielectric at same power. The plasma treatment increased the surface energy of polycarbonate and hence increased hydrophilicity. The contact angle decrease exponentially not only with increase of treatment time but also with increase of applied voltage. An interesting result was found regarding the effect of treatment time on weight loss. Normalized weight loss is found to be increased first for few minutes of treatment then saturated after 5 minutes. This proved that at initial stages of treatment the loosely bounded contaminants and the outermost macromolecules eject out rapidly for the polycarbonate sample in the form of volatile organic products.

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