AXIC APPLICATION REPORT

PLASMA TREATMENT OF MATERIALS FOR MEDICAL APPLICATIONS: OCULAR LENSES - WETTABILITY PROPERTIES

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PLASMA is widely used in IC fabrication for processing of various dielectric, organic and metallic materials. Moreover, it can be used in many other applications for achievement and modification of properties such ***as wetting, dyeing, printing adhesion and biocompatibility*** of organic materials [1,2]. Plasma pretreatment in an oxygen and/or inert gas plasma may influence subsequent chemical processes. Various gases may affect the wettability of a surface in a different way. Generally, the samples pretreated in an oxygen (and/or inert gas) plasma exhibit higher wettability in water and chemical solutions. The effects occurring in oxygen gas due to UV irradiation under vacuum, e.g. photoexcitation, photoionization and photo-radicalization, are enhanced by plasma (ion interaction with surfaces). The pretreatment in halogenized hydrocarbons increases the contact angle, e.g. decreases the surface wettability. A short overview of various plasma processes and their effect on surfaces of different materials is shown in Table 1.

TECHNIQUE AND PROCESS BACKGROUND

Various reactor configurations are used for plasma treatment of surfaces. Often a reactor with parallel plate electrodes is used. This provides good thermal contact between the sample and electrode and protects them from overheating. Placement of samples on the grounded electrode reduces the ion bombardment. However, electrodeless plasmas are used more often to reduce to a minimum physical sputtering. Ion bombardment is avoided in reactors with Faraday traps or downstream (afterglow) reactors. The operating pressures are in the range 0.4 - 7 torr. Radio frequency or microwave plasmas are normally involved at moderate power level (~200 W).

The products of AXIC (Santa Clara, California [3]) cover most of the used electrode and reactor configurations for mentioned applications. One of the simplest but more powerful systems is the MultiMode HF-8, which can serve in parallel plate, cylindrical or tray configurations.

The pretreatment of Acrylic samples in an O_2/Ar plasma [3] may serve as an example for improving surface wettability improvement when using the MultiMode HF-8. In the next section we will demonstrate wetting improvement capability of our plasma systems.

PROCESS AND RESULTS

Acrylic plastics lenses (Lucite-ES) were treated [4] in plasma to investigate an influence of various process conditions on the wettability of surfaces. They were processed in the Multimode HF-8 (13.56 MHz) with a planar electrode setup using a typical process such as: powered upper electrode powered at 150-200 W, bottom

electrode at room temperature, pressure of gas mixture Ar and oxygen is usually in a range of 700-1000 mtorr. Typical plasma treatment time is 3 min. Plasma-to-electrode bias voltage at these conditions is about 16-18 V. The choice of these parameters was selected to provide identical condition for the tray or diode electrode configuration. Two different mixtures of oxygen and argon were used for the pilot experiment.

The contact angle as a measure of wettability by distilled water was used to measure before and after plasma cleaning status. The NRL contact angle goniometer (Rame-Hart, Inc.) was used. The contact angle measurements for different process condition are illustrated on the Fig. 1.

TABLE 1
General remarks on plasma treatment of materials [2].

PLASMA	MATERIAL	REMARKS
oxygen plasma (removing organic substances, residue from packaging, surface cleaning for next operation	*polyethylene, polypropylene, PMMA*	*higher power and higher concentration increase wettability, improve printing, antistatic properties*
nitrogen plasma	*fluorocarbons*	*improve wetting, printing and antistatic properties*
	polystyrene	*wettability and printing*
CF_4	*polyetylene, epoxy-acrylic films, PMMA*	*increase of contact angle - lower wettability through the formation of C-F linkages, improved chemical resistance*
SO_2	*generally for organic materials*	*improved wettability*
inert gas	*metals*	*enhanced resistance to corrosive attack, improved adhesion*

THE INFLUENCE OF PROCESSING PARAMETERS ON WETTABILITY OF ACRYLIC SURFACES

The results on treatment of the Acrylic plastics, e.g. the effects of gas mixture (Fig. 2), duration of plasma treatment (Fig. 3) and oxygen pressure (Fig. 4) will be discussed in this section.

Gas Composition

It is evident from Fig. 2 that an increased content of oxygen in argon has decreased contact angle of the Acrylic surface. The highest wettability of surface was achieved when samples were treated in a pure oxygen plasma, as the argon atoms are replacing the oxygen content in a mixture, the effect is less significant. At low oxygen content in a gas mixture the proposed chemistry is not more involved in the surface processes (contact angle increases up to 43°).

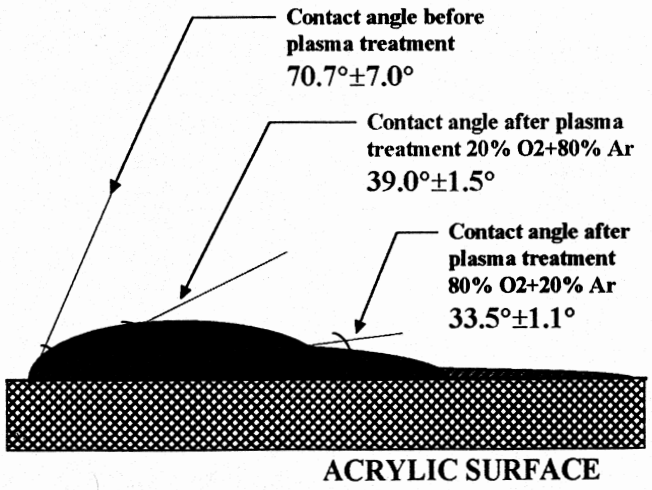

FIG. 1
Illustration of contact angle dependence on processing parameters.

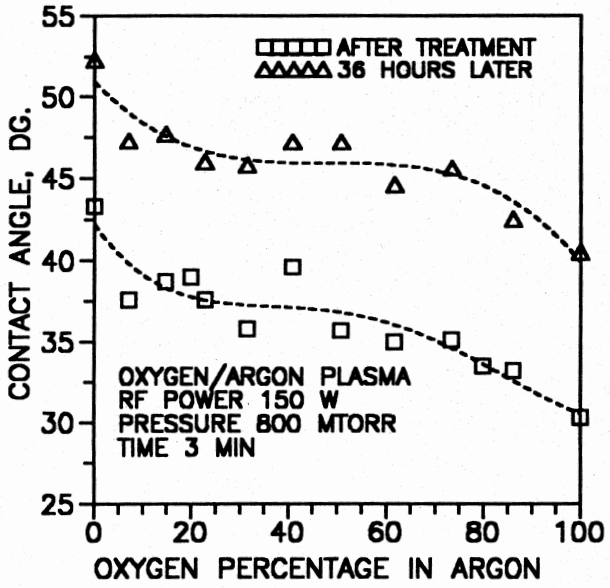

FIG. 2

The dependence of contact angle on composition of gas mixture (oxygen in argon). Rf power was 150 W, total pressure - 800 mtorr, treatment time was 3 min. The identical set of samples was measured 36 hours later.

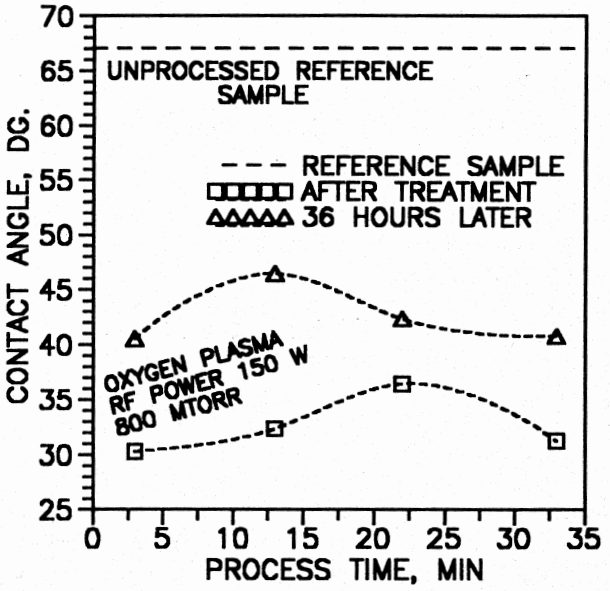

FIG. 3

The dependence of contact angle on processing time in oxygen plasma. Rf power was 150 W, total pressure - 800 mtorr. The identical set of samples was measured 36 hours later.

Processing Time

An attempt was made to find out if processing time of 3 minutes is sufficient time for improved wettability of Acrylic surface. From our measurements (presented in Fig. 3) it is evident that long duration does not improve wettability, moreover we observed an increase in contact angle. More experiments needed to verify this result. Therefore, an extra experiment for 33 min. processing time was performed, in which the wettability was improved practically up to the original values obtained by short-time processing), however, we suppose that longer processing times are not applicable for treatment of lenses because of the heat produced by plasma.

Pressure of Processing Gas

Several experiments were done using different pressures of oxygen. The dependence of contact angle on oxygen pressure is shown on Fig. 4. The optimal pressure region for improvement of wettability is above 700 mtorr.

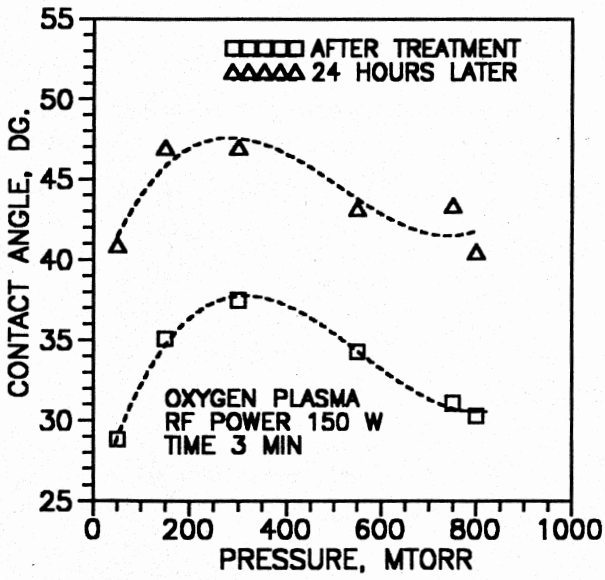

FIG. 4

The dependence of contact angle on pressure of oxygen. Rf power was 150 W, time of processing was 3 min. The identical set of samples was measured 24 hours later.

In our opinion, at moderate pressures, the increase of contact angle is due to smaller oxygen concentration in the plasma. A dramatic decreasing of contact angle at pressures bellow 250 mtorr is probably produced by bombardment of the surface by more energetic ions. We suppose that at such condition the surface is not modified by oxygen-surface chemistry, but by physical interaction of impinging ions. It may be expected that this surface will be more damaged. From the application point of view, in this case the shape of lens could be affected by anisotropic properties of plasma-surface phenomena.

Aging of Plasma Treated Samples

The measurements of the original set of samples 24-36 hours after plasma treatment resulted in contact angle increase with time after processing.

The behavior of contact angle dependence on oxygen pressure was repeated and the results traced nearly with the first data.

CONCLUSION

i) The highest improvement of wettability of the Acrylic surface was obtained in pure oxygen plasma (from original contact angle of 70.7° down to 33.5°). Addition of argon reduces the wettability of surface to 43°.

ii) The optimal operation pressure is above 750 mtorr. At pressure below 150 mtorr a reduction of contact angle occurs again (an increase of wettability can be observed), however, we concluded that this effect has to be anisotropic.

iii) Processing time of several minutes (2-3 min) is sufficient for improved wettability. Prolonged times of plasma treatment does not improve wettability significantly.

iv) When aging of samples occur the wettability decreases, however, the behavior of surface modification in respect to wettability in dependence on process condition is permanent.

v) The use of plasma treatment for medical applications - surface modification of the intraocular lenses - has a positive effect and a potential to become a practical choice for biocompatibility improvement.

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[2] **Boenig, H., *Fundamentals of plasma chemistry and technology*, Technomics Publishing, Lancaster-Basel (1988).**

[3] ***see, for example, AXIC on Internet: http:/www.axic.com, (1996***

[4] **Brcka, J., *Plasma Treatment of Surfaces, in: Plasma Application Report*, AXIC, Santa Clara, CA (1996).**