Contact Angle Measurements and Surface Analysis of Atmospheric Pressure Plasma Treated Polypropylene

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Introduction

The Surface Analyst™ rapidly obtains contact angles from surfaces via Ballistic Deposition, whereby a small drop of liquid (usually water) is constructed *in situ* on the surface via a pulsed stream of nanoliter-sized droplets. The contact angles established in this manner are a sensitive function of surface chemical composition. In this work, injection molded polypropylene panels were oxidized to various levels via exposure to an atmospheric pressure plasma treatment process. Surface chemical composition was determined via X-ray Photoelectron Spectroscopy (XPS), and the chemical composition was related to the water contact angles determined using a Surface Analyst™.

Experimental

Substrates: High purity, additive-free polypropylene plaques (Lyondell Basell, Lansing, MI) were wrapped in aluminum foil immediately after injection molding with care begin taken to avoid contact of the surfaces. Samples were unwrapped immediately prior to treatment and then analyzed via XPS and/or contact angle measurements within an hour.

Surface preparation:

Plasma treatments were performed using air at atmospheric pressure (single rotary plasma jet RD1004, Plasmatreat North America Inc., Mississauga, ON). An electrode gun that produces a stream of low temperature ionized gas is mounted on a robotic arm with controllable traverse rate, pitch (lateral distance between successive traverses), and sample/gun distance. Samples received treatment with a fixed traverse rate of 6"/second while the gun-sample distance was varied from 0.4" to 1.0". Pitch was held constant at 0.7".

Surface energy measurements: Ballistic contact angles of distilled, deionized water were obtained using a Surface Analyst™ (Brighton Technologies Group, Inc., Cincinnati, OH).

X-ray photoelectron spectroscopy: XPS spectra were obtained using a SSL M-probe using monochromatic Al k_α X-rays with an 800μm spot size. Three separate spots were analyzed on each specimen with the atomic compositions reported as an average of these three separate locations.

Results and Discussion

Figure 1 shows the Ballistic Contact Angle of water as a function of the plasma jet to surface distance. Untreated plaques showed >90° contact angle; decreasing the distance from plasma jet to surface at a constant traverse rate resulted in a linear decrease in the contact angle. Once the jet was 0.6” away from the surface, further decrease in the distance resulted in much less change in contact angle.

Figure 2 shows the corresponding atomic % oxygen detected in the polypropylene surface as a function of plasma jet to surface distance. Decreasing the distance from plasma jet to surface at a constant traverse rate resulted in a linear increase in the amount of oxidation of the polypropylene.

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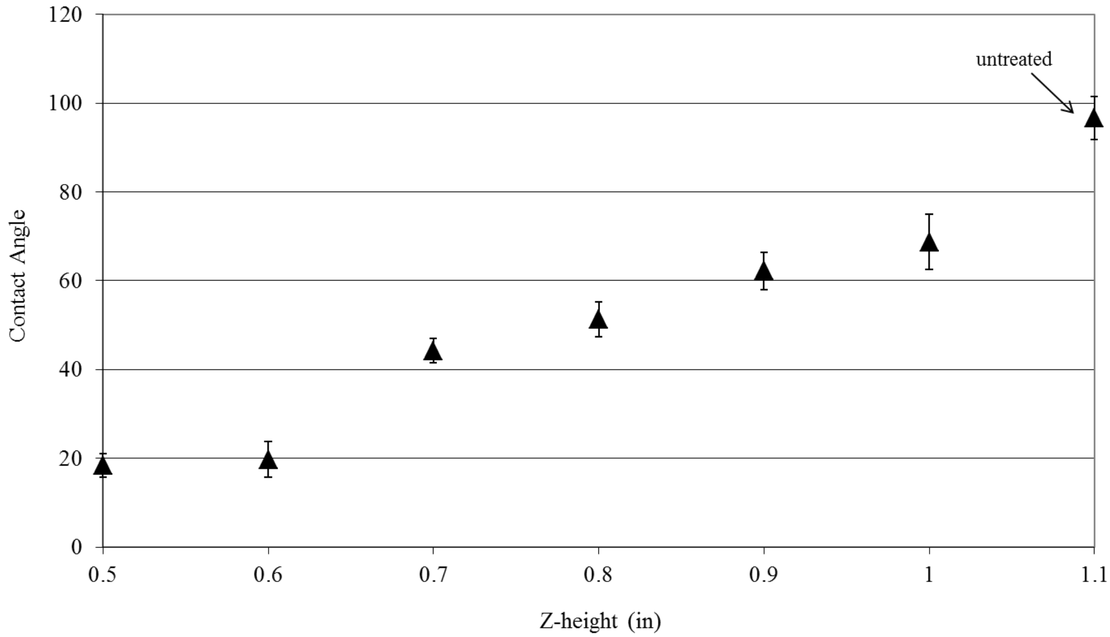

Figure 1. Ballistic contact angle of water versus plasma jet to surface distance for atmospheric pressure plasma treated polypropylene.

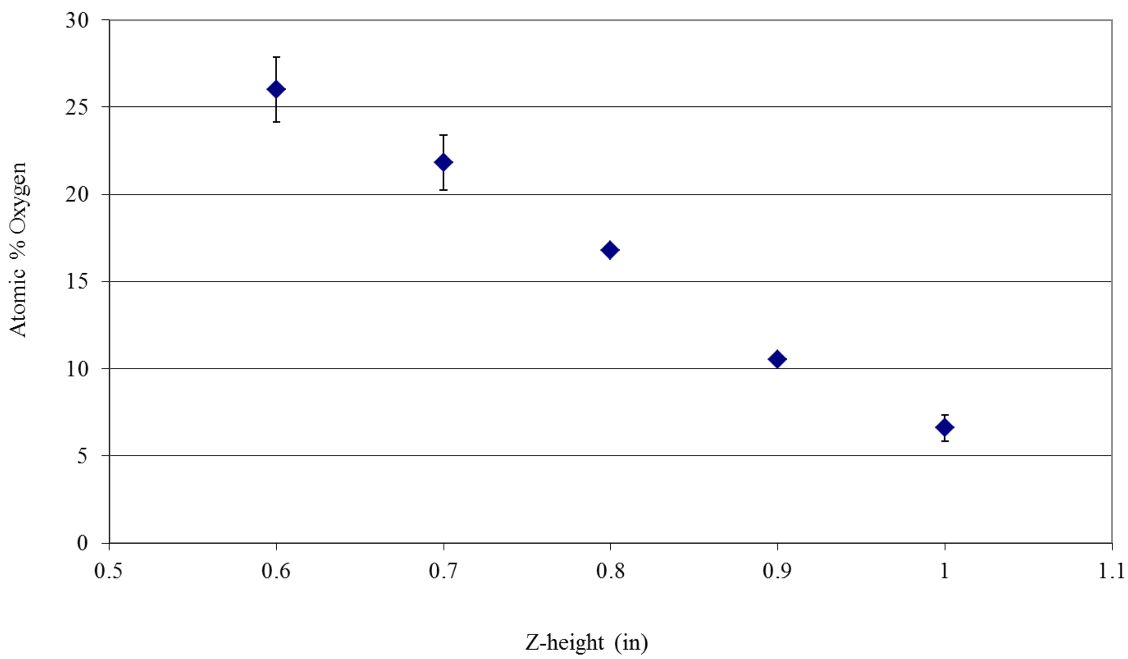

Figure 2. Relative atomic % oxygen versus plasma jet to surface distance for atmospheric pressure plasma treated polypropylene.

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The linear relationship of Ballistic Contact Angle of water and atomic % oxygen to treatment conditions indicate that there is a linear relationship between the Ballistic Contact Angle and atomic % oxygen. Figure 3 shows this relationship, which shows that Ballistic Contact Angle measurements are strongly correlated with the surface chemical composition of atmospheric pressure plasma treated polypropylene in an approximately linear fashion.

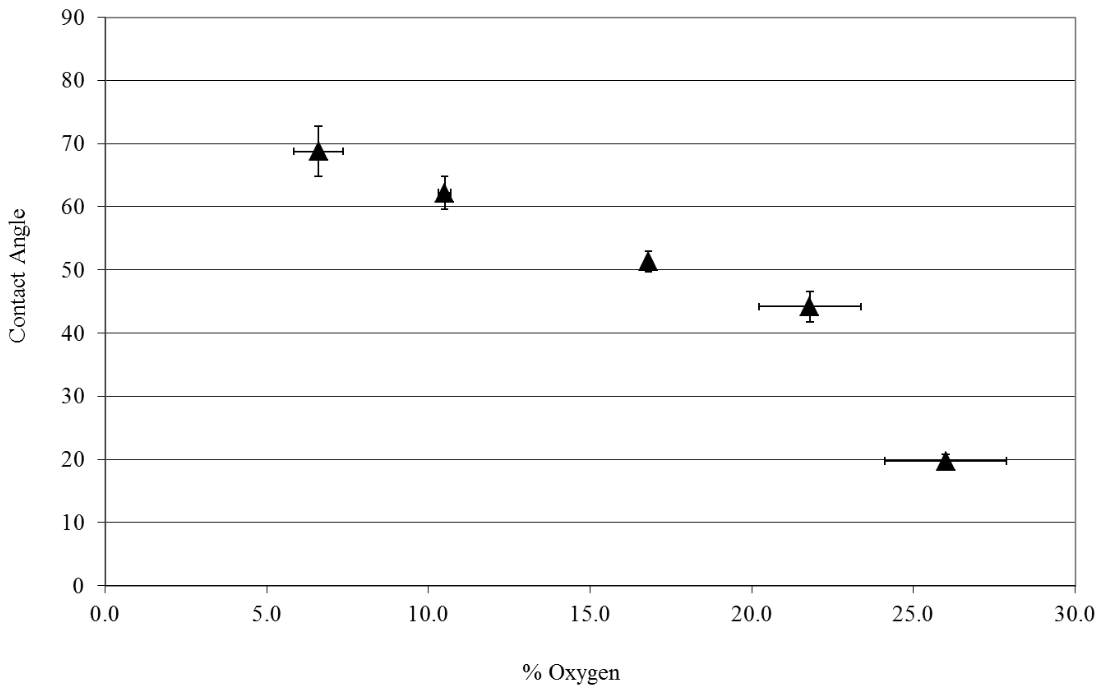

Figure 3. Correlation of Ballistic Contact Angle of water with relative atomic % oxygen for atmospheric pressure plasma treated polypropylene.

Conclusions

1. Atmospheric pressure plasma treatment provides readily controllable levels of oxidation of the surface of polypropylene.
2. Ballistic Contact Angles of water with these surfaces correlate well with the level of oxidation. This correlation is approximately linear.

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