Comparative investigation of BOPP foil surface treatment using various atmospheric-pressure plasma sources

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Biaxially oriented polypropylene (BOPP) films are produced by stretching melted polypropylene in both machine and transverse directions, resulting in thin, transparent, and durable sheets. These films are widely used in the electrical industry for capacitors and food packaging due to their chemical resistance, optical properties, strength, lightweight nature, low toxicity, and moisture barrier properties. However, due to polypropylene's hydrophobic and low-surface energy nature, limitations arise in composite materials, printing, dyeing, and coating industries. To address this, the wettability and adhesion properties of BOPP films can be improved through various surface modification techniques, including physical, chemical, UV, and plasma treatments [1]. One of the most commonly used methods for surface modification of polymers is cold plasma treatment, mainly generated by dielectric barrier discharges (DBDs) at atmospheric pressure. This method offers several advantages, including fast treatment, absence of toxic waste and solvents, effortless control, dry process, and anisotropic effects. Depending on the plasma source configuration and working gas, various chemical functional groups and free radicals can be generated, significantly altering the polymer surface properties [2]. In this comparative study, we subjected the thermally sensitive BOPP film to various atmospheric-pressure plasma sources, with exposure times of 1, 5, and 10 seconds, and utilizing different working gases. The plasma sources employed were as follows: a nitrogen multi-hollow surface dielectric barrier discharge (MSDBD) [3], an argon cylindrical plasma jet array [4], a diffuse coplanar surface barrier discharge (DCSBD) generated in ambient air and nitrogen gas [5], and a linear nitrogen DCSBD-based plasma system. To assess the wettability, morphology, and surface chemical composition of the plasma-treated BOPP film, we employed water contact angle (WCA) measurement, scanning electron microscopy (SEM), atomic force microscope (AFM), and X-ray photoelectron spectroscopy (XPS) analyses. Furthermore, the adhesion properties were evaluated through peel force measurements. The most significant decrease of the WCA to 37.9° compared to the reference sample's value of 100.8°, was observed immediately following treatment with the linear nitrogen DCSBD-based plasma system. Furthermore, adhesion increased approximately fourfold immediately after treatment with air DCSBD. Overall, our findings demonstrate the effectiveness of various atmospheric-pressure plasma sources in modifying the wettability, surface morphology, and chemical composition of thermally sensitive BOPP films. These results highlight the potential of plasma treatment for enhancing the adhesion properties of BOPP films. Moreover, treatment with all plasma sources resulted in increased wettability, even after just 1 second of plasma exposure.

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