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Analysis of Low-Temperature Plasma Treatments on Polymer Surface Properties

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Polymeric materials are widely used across industries due to their low weight, high mechanical strength, chemical resistance, and cost-effectiveness. Despite these advantages, most polymers exhibit low surface energy and hydrophobicity, which limit their performance in applications such as coating, adhesion, painting, and composite interfaces [1]. Consequently, surface modification has become essential to enhance polymer functionality. The modification of polymer surfaces using low-temperature plasma (LTP) treatments has attracted significant attention due to its effectiveness in improving surface properties without altering bulk characteristics [2]. However, the desired surface changes on the polymer substrate induced by plasma treatment are not permanent and gradually revert to the initial state. This behaviour is called hydrophobic recovery or the ageing effect. It depends on many parameters, such as the properties of the polymer substrate, the type of plasma source, plasma treatment conditions, and storage conditions. The relationship and mutual effects of these conditions on the stability of plasma-induced changes and the rate of hydrophobic recovery are still not fully understood.
In this study, we investigate low-temperature plasma treatments of the surface properties of polyamide (PA), polypropylene (PP), and polycarbonate (PC). Two plasma systems, Diffuse Coplanar Surface Barrier Discharge (DCSBD) [3,4] and Piezobrush PZ3 [5], were employed to assess their effectiveness in modifying surface free energy, wettability, and chemical composition. Surface characterisation was conducted using Water Contact Angle (WCA) measurements and Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR). The ageing effect was monitored under three different storage conditions: water, vacuum, and ambient room temperature. The results demonstrate that both plasma treatments significantly enhance surface energy and wettability for all polymers, accompanied by chemical modifications that improve surface functionality. The study of hydrophobic recovery provides a complex view of how individual parameters of plasma treatment (such as plasma source and exposure time), along with different storage conditions, influence the rate and degree of hydrophobic recovery. This analysis offers valuable insights for selecting suitable plasma sources in polymer surface engineering applications, including adhesion improvement, coating, and biocompatibility enhancement.

Keywords
Low-temperature plasma, Polymers, DCSBD, hydrophobic recovery, surface modification

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Author: GAHRAMANLI, Sahila (Comenius University Bratislava)

Co-authors: ZAHORANOVÁ, Anna (Comenius University Bratislava); ŠRÁMKOVÁ, Petra (Comenius University Bratislava)

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