Analysis of Low-Temperature Plasma Treatments on Polymer Surface Properties

Motivation

Polymers' low surface energy limits their performance in adhesion, coating, and biomedical applications. Effective surface modification, such as low-temperature plasma treatment, is crucial to enhance their functionality.

Introduction

This study explores the surface modification of Polyamide (PA), Polypropylene (PP), and Polycarbonate (PC) using two different plasma sources.:

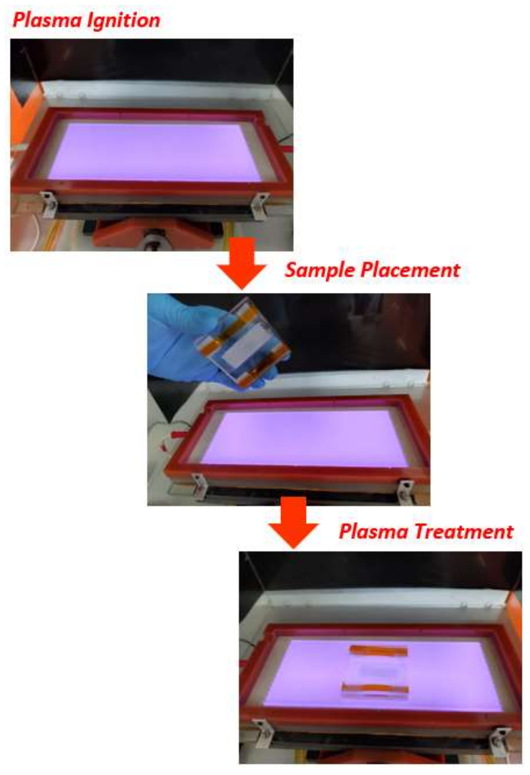
- Diffuse Coplanar Surface Barrier Discharge (DCSBD)
- Piezobrush PZ3 plasma system

Goals

- To compare how each plasma source affects:
  - ✓ Surface energy
  - ✓ Wettability
  - ✓ Chemical composition treatment
  - ➢ Water Contact Angle (WCA)
  - ➢ ATR-FTIR Spectroscopy
- Monitoring the ageing of plasma under various storage conditions.

Plasma Systems

DCSBD



Feature / Source	DCSBD	Piezobrush PZ3
Plasma Type	Cold atmospheric-pressure plasma (diffuse, homogeneous)	Cold atmospheric-pressure plasma (piezoelectric direct discharge)
Power Supply	400 W, ~15 kHz sinusoidal voltage, 20 kV (peak-to-peak)	8 W (at 100% power setting), 50 kHz, sinusoidal waveform, ~ 40 kV (peak-to-peak)
Power Density	1–3 W/cm² (surface), 100 W/cm³ (volume)	Low power consumption for small-area applications
Active Plasma Area	8 x 20 cm²	d = 5.5 mm, ≈612.7 ± 13.19 mm²
Plasma Layer Thickness	0.3 mm	5 mm
Operating Mode	Continual regime (continuous operation)	Handheld (mounted in a vertical position)
Operating Environment	Atmospheric pressure, safe in humid and dusty environments	Standard ambient conditions
Advantages	High-density homogeneous plasma, suitable for large-area treatments	Compact, portable, ideal for delicate surface activation

Piezobruh PZ3

Plasma treatment

- Sample Dimensions: 1.5 × 4 cm
- Treatment Durations: 1, 3, 5, 10, 20, and 30 seconds
- Surface Characterisation: immediately, post-treatment, and subsequently during ageing studies

Results

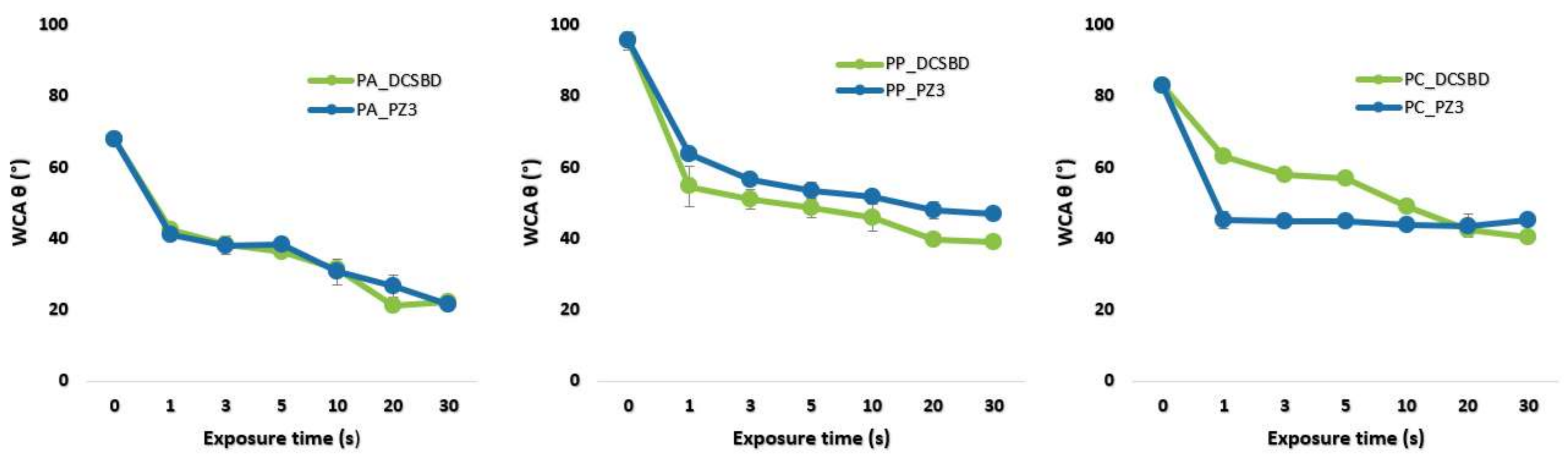


Fig. 1. Comparative analysis of DCSBD and Piezobrush PZ3 plasma treatments on PA, PP, and PC

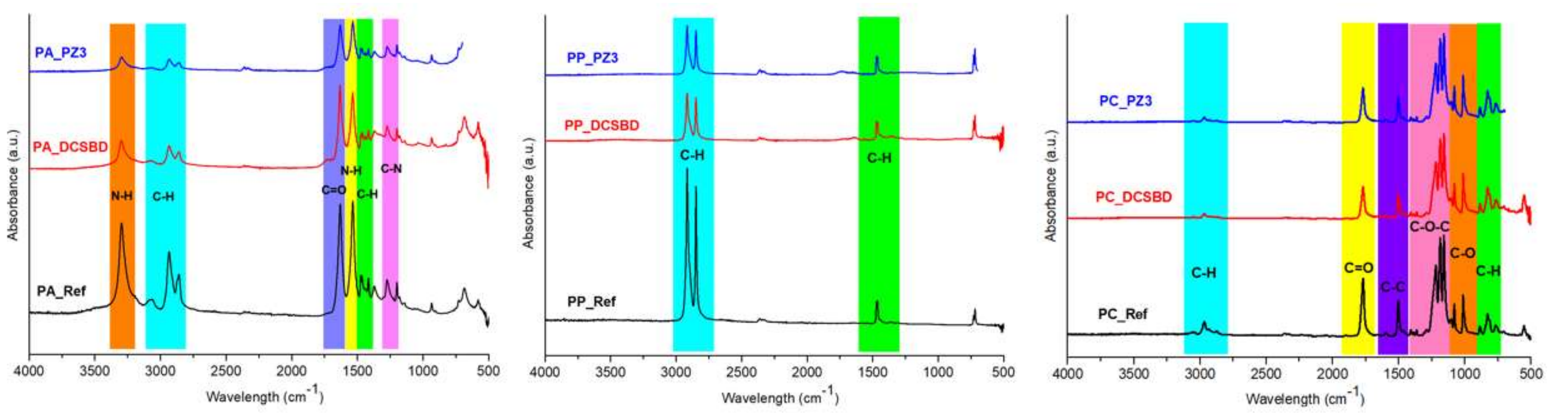


Fig. 2. ATR-FTIR spectra of PA, PP, and PC polymers after DCSBD and Piezobrush PZ3 plasma treatments

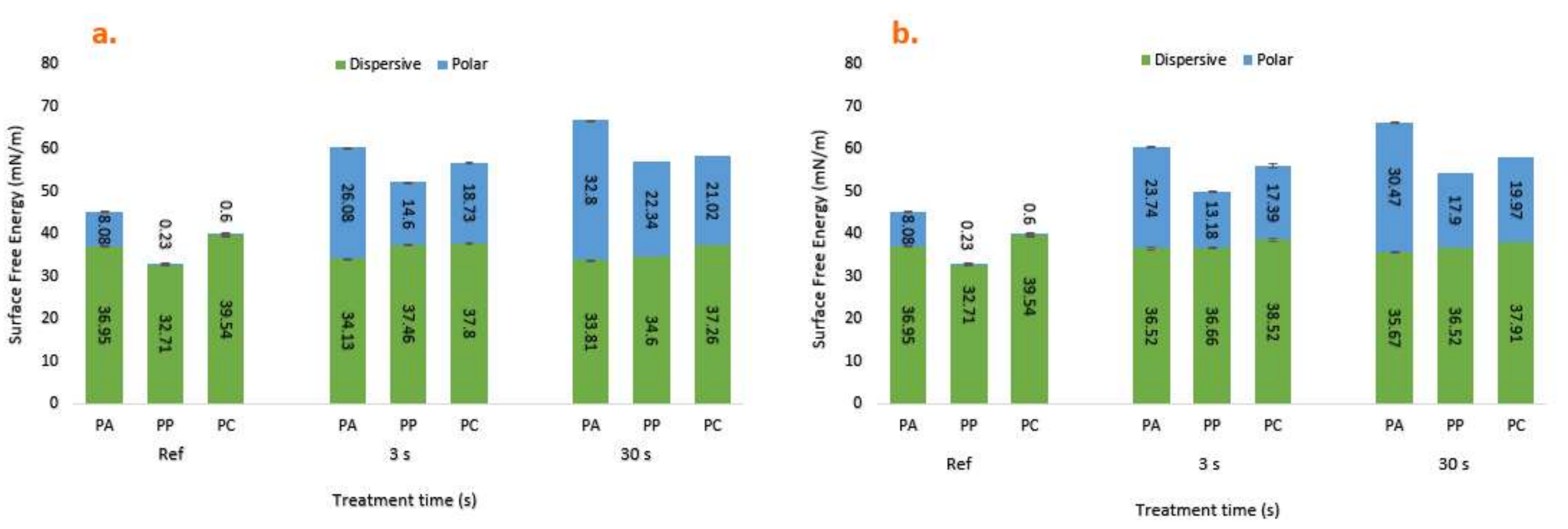


Fig. 3. Effect of DCSBD and Piezobrush PZ3 Plasma Treatments on Surface Free Energy of PA, PP, and PC Polymers

a. DCSBD
b. Piezobrush PZ3

Aging Effect

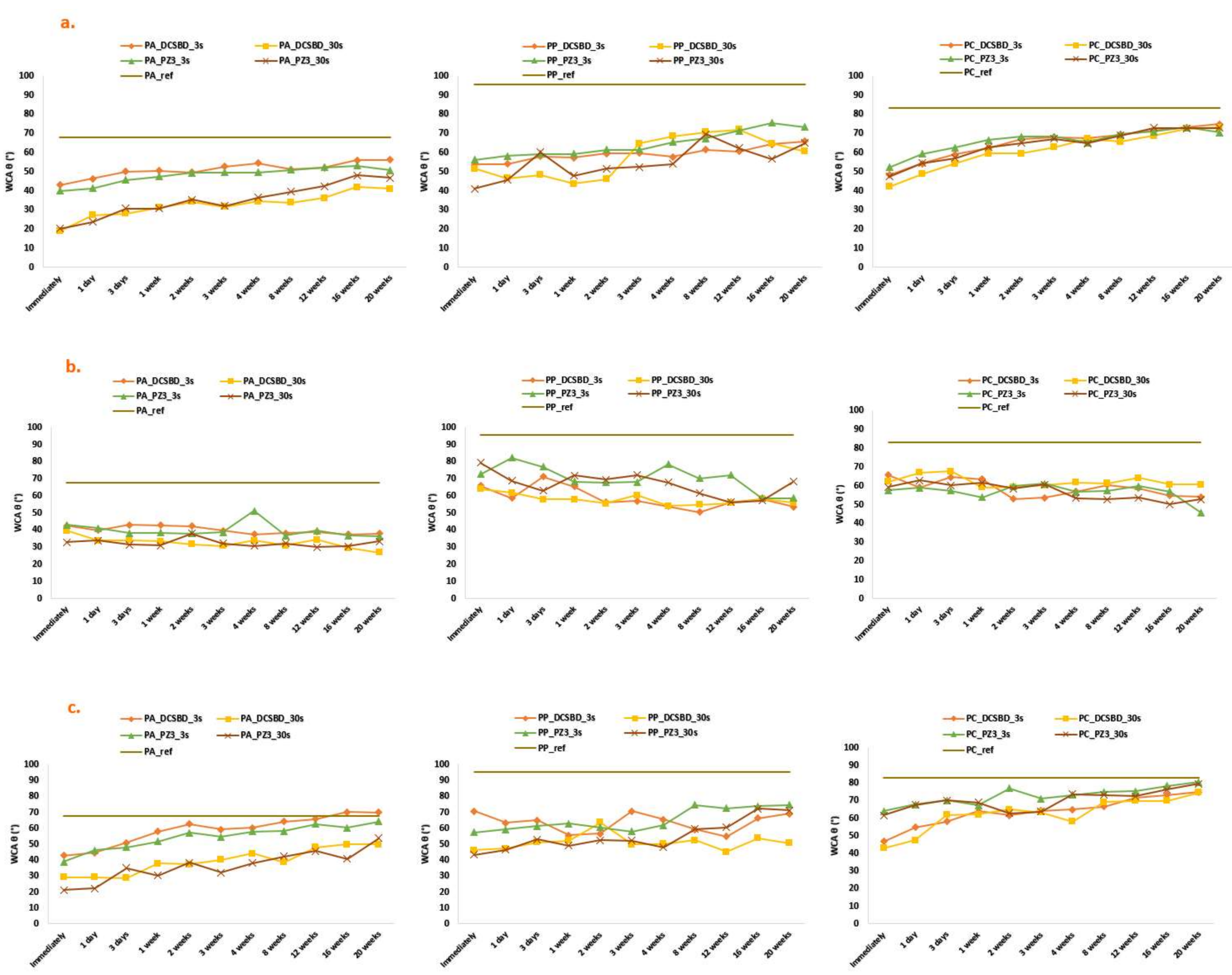


Fig. 4 . Monitoring the ageing effect in different conditions during 3 months - wettability stability of PA, PP, and PC polymers treated with DCSBD and Piezobrush PZ3 plasma

a. Room Temperature (RT)
b. Water
c. Vacuum

Conclusions

1. DCSBD and PZ3 plasma treatments increased the hydrophilicity of PA, PP, and PC polymers, and wettability efficiencies were similar.
2. No new peaks were observed following plasma treatments, indicating that the plasma treatment only affected the nanometre-thin layer of the polymer surface.
3. Both plasma treatments effectively increased the surface free energy of the polymers, particularly strengthening the polar component during the 30-second treatment period, and the effectiveness for SFE was similar.
4. Over time, an increase in contact angle was observed in all conditions, and the surfaces partially returned to their previous state, depending on the duration of plasma exposure and the storage conditions used.

Plasma treatments effectively altered the polymer surface, increasing its surface energy and hydrophilicity. However, it should be noted that these changes were not permanent and that durability depended on storage conditions.

References

1. Yoshida S. et al., Surf. Coat. Technol., 2013.
2. Bîrleanu E. et al., Polymers, 2023.
3. Štěpánová V. et al., Vacuum, 2021.
4. Černák M. et al., EPJ-AP, 2009.
5. Korzec D. et al., Plasma, 2022.

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