Plasma assisted bio-degradation of poly-lactic acid (PLA)

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Introduction

Plastics are artificial synthetic organic polymers that have been used in every area of daily life. However, because of their slow degradation rate, their use is contentious. The treatment of the surface of the sample is considered necessary as enzymatic or bacterial attach is not possible, if the plastic surface environment is not ideal. The main topic of this work is the investigation of the effect of atmospheric dielectric barrier discharge (DBD) plasma on the near surface structure of polylactic acid (PLA) samples, which, in turn, can promote the adhesion of enzymes or bacteria for further biodegradation. In general, plasma processes can already be considered as inherently environmental technologies.

Plasma processes enable resource saving through high energy utilization efficiency and thus, are environ-mentally friendly technologies. Atmospheric pressure discharges (APDs) are useful because of their specific advantages over low-pressure ones. They do not need expensive vacuum equipment, and generate nonthermal plasmas, which are more suitable for assembly line processes. Hence, this category of discharges has significant industrial applications. The use of a dielectric barrier in the discharge gap helps prevent spark formation. DBDs exhibit two major discharge modes: filamentary and glow (homogeneous). The glow discharge mode has obvious advantages over the filamentary one for applications such as treatment of surfaces and deposition of thin films. Glow mode discharges with average power densities comparable to those of filamentary discharges are of enormous interest for applications in which reliable control is required.

Here we will present the increased adhesion of bacteria strains on DBD plasma treated PLA foils which can lead to a better degradation of the PLA. X-ray photoelectron spectroscopy (XPS) measurements of the foils prior to and after the treatment proved the changes on the polymer surface. A short discussion of the possibilities the treatment opens is given.

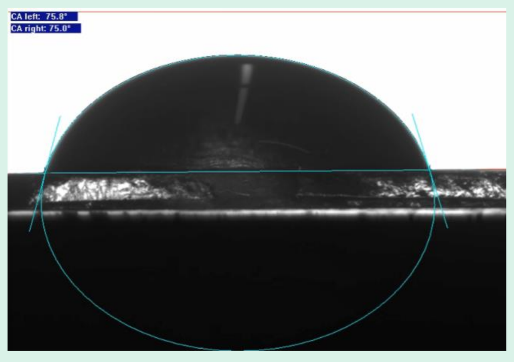
Experimental part

The polymer foil samples are cut to pieces of 1 x 1 cm^2 and characterised using XPS, FT-IR, confocal laser microscopy (CLSM), and drop contour analysis. Further, we developed an in-house DBD atmospheric plasma reactor (Fig. 1) for treatment of solid samples. Here we will mainly present degradation of polymer foils using atmospheric plasma in ambient air.

Fig. 1 *: In-house atmospheric DBD-plasma reactor for the treatment of polymer foils*

Results….

Fig. 2 *: Contact angle measurements of the plasma activated PLA surface. A decreased contact angle means an increased surface hydrophilicity*



Sample name	Angle Left [°]	Angle Right [°]
PLA Reference	69.2	70.2
PLA_5s Plasma	53.4	52.9
PLA_10s Plasma	50.8	50.1
PLA_20s Plasma	49.7	53.8
PLA_60s Plasma	53.6	53.7

….Results

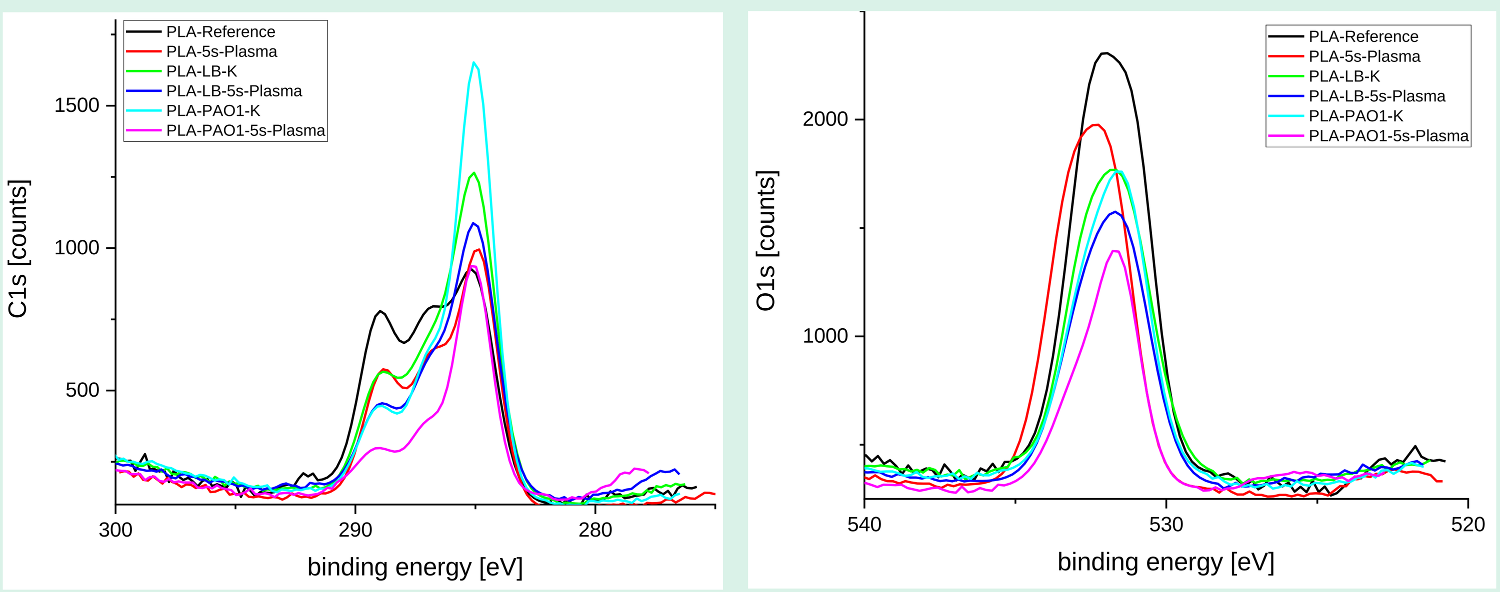


Fig. 3 *: XPS spectra : (left) the carbon signal and (right) the oxygen signal*

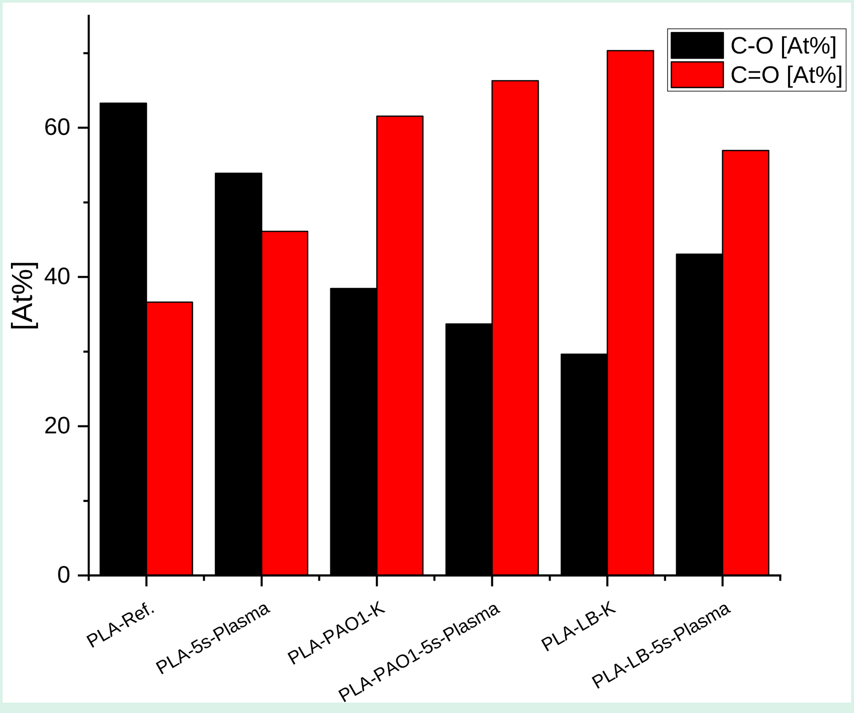


Fig. 4 *: Deconvolution of the C1S signal shows a shift from C-O bonds to C=O bonds due to plasma treatment.*

Fig. 5*: Bacteria strain sticking on the surface of the plasma treated PLA.*

Conclusions

Advanced Oxidation Processes can improve the degradation of polymers. Using atmospheric DBD plasma we observe an oxidation of the surface, which lies more on the reduction of the C–C bonds relative to the C–O and C = O bonds. We tested pre-treated PLA foils regarding a possible improved adhesion of bacteria strains and found in the example of the pseudomonas knackmussii and especially pseudomonas aeruginosa strains that depending on the pre-treatment method the adhesion has been substantially improved. Recently we have shown the possibility of the valorization of enzymatic PLA degradation products to nanocellulose [1].

[1] Georgia Sourkouni, S. Jeremić, Ch. Kalogirou, O. Höfft, M. Nenadovic, V. Jankovic, D. Rajasekaran, P. Pandis, R. Padamati, J. Nikodinovic-Runic, Chr. Argirusis, "Study of PLA pre-treatment, enzymatic and model-compost degradation, and valorization of degradation products to bacterial nanocellulose", World Journal of Microbiology and Biotechnology (2023) 39:161 . https://doi.org/10.1007/s11274-023-03605-4

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