

Taking Advantage of the Versatility and Multifunctionality of Plasma Polymers

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Plasma polymers (PPs) do not have a well-defined structure of conventional polymers that can be described as a repetition of a particular unit and the molecular weight of the polymer chain. Since they are deposited from a complex environment of gaseous species formed by the electron impact dissociation of the original gas feed, their chemical structure cannot be derived only from the starting reactants. PPs contain a mixture of chemical functionalities and have a structure resembling cross-linked macromolecules rather than polymers. It might be seen as a disadvantage, but proteins and other biomolecules are also extremely complex, and nature takes advantage of it.

Inspired by nature, PPs containing carboxyl ($-\text{COOH}$) and primary amino ($-\text{NH}_2$) groups have been proposed for bioapplications because, besides hydrophilic surfaces, they can form amide bonds with the respective $-\text{NH}_2$ and $-\text{COOH}$ counterparts. It allows the immobilization of collagen, fibronectin, growth factors, and other biomolecules to improve surface biocompatibility [1]. The disadvantage of using amine PPs is their tendency to oxidize. Carboxyl PPs, which exhibit high stability in air, are often preferred when the application does not specifically require positively charged surfaces or the presence of amino groups [2]. I will review both bioactive types of PPs and compare their efficiency in binding lignin nano- and microparticles on PP-coated polymer nanofibrous membranes [3] and the construction of immunosensors [4]. Focusing on amine PPs, I will discuss the consequences of their multifunctionality (presence of unsaturated bonds, trapped radicals, and fluorescence nanoparticles) and chemical bond rearrangement with plasma parameters.

Plasma polymerization is a versatile process for coating various types of substrates, and its advantages over chemical methods include independence from the substrate material, environmental friendliness, and one-step, fast processing. Coatings can be applied on complex 3D substrates, such as nanofibrous mats [1,3]. Yet, the processes in cavities and porous materials need to be better understood, as the action of ions (etching or deposition) becomes limited, and film-forming species with low sticking coefficients might dominate. Herein, I will demonstrate the use of cavities with slits and undercuts as experimental tools for understanding PP on 3D substrates, especially for carboxyl PPs, for which deposition can be close to the deposition-etching balance [5].

Affix**References**

- [1] A. G. Guex, D. Hegemann, M. N. Giraud, H. T. Tevaeearai, A. M. Popa, R. M. Rossi, and G. Fortunato, 'Covalent immobilisation of VEGF on plasma-coated electrospun scaffolds for tissue engineering applications' *Coll. Surf. B* 123 (2014) 724
- [2] M. Buchtelová, L. Blahová, D. Nečas, P. Křížková, J. Bartošíková, J. Medalová, Z. Kolská, D. Hegemann, and L. Zajíčková, 'Insight into peculiar adhesion of cells to plasma-chemically prepared multifunctional "amino-glue" surfaces' *Plasma Process. Polym.* 20 (2023) e2200157
- [3] L. Janů, N. Souawda, R. Anand, D. Duday, J. Medalová, D. Collard, D. Nečas, K. Polášková, P. Ryšánek, J.-S. Thomann, M. Janůšová, and L. Zajíčková, 'Immobilization of lignin nano/microparticles on plasma-modified polymer nanofibers' *International Journal of Biological Macromolecules* 343 (2026) 150226
- [4] (a) E. Makhneva, Z. Farka, P. Skládal, and L. Zajíčková, 'Cyclopropylamine plasma polymer surfaces for label-free SPR and QCM immunosensing of Salmonella' *Sens. Actuators. B* 276 (2018) 447
- (b) E. Makhneva, Z. Farka, M. Pastucha, A. Obrušník, V. Horáčková, P. Skládal, and L. Zajíčková, 'Maleic anhydride and acetylene plasma copolymer surfaces for SPR immunosensing' *Anal. Bioanal. Chem.* 411 (2019) 7689-7697
- [5] M. Janůšová, D. Nečas, P. Navascués, D. Hegemann, S. Gavranovic, and L. Zajíčková, 'Insight into plasma polymerization with a significant contribution of etching to the deposition process' *Surf. Coat. Technol.* 503 (2025) 131962