Industrial applications of highly non-equilibrium low-pressure oxygen plasma

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Low pressure gaseous plasma is a suitable medium for tailoring surface properties of solid materials on industrial scale. Treated materials are subjected to positively charged atomic and molecular ions, neutral radicals and ultraviolet as well as vacuum ultraviolet radiation. The penetration depth of ultraviolet radiation in organic materials is around a micrometre so it is suitable for modification of rather thick surface layers and triggering structural modifications such as cross-linking [1]. Vacuum ultraviolet radiation has penetration depth of around 10 nm, so it is particularly suitable for breaking bonds between atoms in the surface layer. The neutral radicals usually do not penetrate the solid material so they affect the surface only. In most cases, synergistic effects of radiation and neutral radicals are beneficial. Plasma rich in neutral radicals is usually sustained by electrodeless radiofrequency discharges. The coupling of powerful generators with plasma in industrial-size reactors is not trivial at frequencies around 10 MHz due to prohibitively large impedances so innovative solutions that supress the peak voltages such as [2] are beneficial. Oxygen plasma is particularly suitable for improving wettability of carbon-containing materials. The surface is often saturated with polar functional groups after receiving the fluence of O-atoms around $1x10^{22}$ m^{-2}, what is achieved in milliseconds providing the reactor is properly designed. Prolonged treatment causes etching which is often inhomogeneous enough to cause nanostructuring and thus super-wettability of processed materials. Such a surface finish enables excellent adhesion of different coatings, even electrodeposited metallic films [4]. Several other industrial applications of highly non-equilibrium low-pressure oxygen plasma will be presented

[1] M. Lehocky et al, Device and method for producing UV radiation: patent EP3168860B1 (2018).

[2] A, Vesel et al, Device for high-frequency gas plasma excitation: DE 112012000015B4 (2016).

[3] A. Vesel et al, Initial stages in functionalization of polystyrene upon treatment with oxygen plasma late flowing afterglow. Plasma Sour. Sci. Technol. 27 (2018), 094005-1-9.

[4] U. Cvelbar et al, Method for improving the electrical connection properties of the surface of a product made from a polymer-matrix composite: patent EP 1828434B1 (2008).