PO1080

Impact of Atmospheric Pressure Plasma on Polymers: Modification vs. Etching

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Atmospheric-pressure nonequilibrium micro-plasma jets are used in a variety of applications related to surface treatment. Due to their characteristic size, electron density, electron temperature and neutral gas temperature many special applications e.g. cleaning, surface modification and thin film deposition in particular on 3D surfaces are possible. Specifically, plasma based antimicrobial treatment of medical devices comprised of polymeric materials is of increasing interest. Plasma induced functionalization, cross-linking and etching of polymer surfaces leads to chemical and morphological changes that influence the performance characteristics. Process parameters, like power, gas flow conditions and material properties play a role in the appearance of the footprint of micro-plasma jets on the particular surface.In the present work the influence of the chemical composition of polymers on their modification and degradation in argon and argon/oxygen RF plasmas is studied. The distance between substrate and jet nozzle, treatment time and the operating gas mixture are systematically varied. The resulting radial dependence of the surface functionalization and polymer degradation is characterized by X-ray photoelectron spectroscopy (XPS), water contact angle measurements, mass loss measurements and profilometry. Chemical and morphological changes of the plasma treated polymers are observed. Concerning the operation gas, a small oxygen admixture (1 %) leads to an increased incorporation of oxygen when treating polyethylene whereas the same process causes less oxygen content on tetrafluoroethylene-hexafluoropropylene (FEP) as compared to operation with pure argon. Also the contact angle measurements exhibit very different profiles e.g. plasma exposure of polystyrene shows a broadening of the modified area whereas FEP shows less changes with increasing treatment time. The evolution of contact angle of polycarbonate shows a central part and a plateau-like region outside of this central part whereas the contact profile of polyethylene exhibits only a central part with increasing contact angle out of the impinging jet. Concerning the plasma induced degradation high etch rates are obtained depending on the polymer structure e.g. aliphatic carbons are easier to etch than aromatic carbons.

Keywords
Plasma Jet
Polymers
Surface Modification
Etching