Enhanced dielectric barrier discharge system for plasma surface modification

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The newly created triode dielectric barrier discharge (DBD) plasma system is used in a new technological process practice, [1], combining plasma surface activation (functionalization) through surface oxidation and porous media impregnation with phosphor containing flame retardant solution for protection of flammable materials and products [2].

Polymer (wood) large area products – wood floors, wainscoting, plywood, wood and cardboard sets, pressed cardboard, pasteboard, carpeting (polypropylene, polyamide), carpets and so on, are processed. All types of horizontal, vertical and overhead surfaces are processed in the production line or outside it, the protective solution being applied after plasma-chemical surface activation by all known and accessible ways - spill, brush or spray [1].

Half-opened technological plasma system, fig. 1, allows handling of large area surfaces by its sequential 'step by step' movement. This is indirect (remote) surface plasma processing with chemical active particles, produced within the plasma field.

The non-equilibrium (and non-isothermal) cold plasma of the dielectric barrier discharge is used as follows: first, a source of fast electrons (within the volume of the discharge) at direct contact with the surface processed; second, a source of chemical active particles at indirect contact with the surface processed, Fig. 1.

Fig. 1. Half-opened technological diode DBD-plasma system (Peter Dineff, 2005).
In this type of technology the plasma homogeneity is not a leading requirement as in the symmetric diode co-planar plasma system realization, operating at relatively low voltage of \textit{Dow Corning Plasma Solutions} and \textit{Plasma Ireland Ltd.} (Ireland, 2006). This determines the demand for technical resources to increase the intensity not only of the avalanche mode of operation, but also of the streamer modes - whether cathode or anode directed streamers.
The improvement of the technological plasma system is perceived by the discharge real power change \( P_R \), respectively the surface density of the discharge real power \( p_R \) \( (p_R = P_R/S, \text{ where } S \text{ is the electrodes active area}) \) and its distribution depending on the size of the air gap \( d \), Fig. 2. The discharge real power surface density \( p_R \) shall be calculated by a known method, created by the authors (Peter Dineff, 2008), by experimental extraction of the static (volt-ampere) external DBD characteristics [4].

A method, also developed by the authors (Peter Dineff, 2009), [3], allows indirect evaluation of the contribution of any technical solution improving the DBD plasma generation, using the surface density of discharge real power.

Fig. 2 shows the DBD-discharge streamer modes area - peak B, the cathode directed streamers area; peak C, the anode directed streamers area. It can be seen that the peak A area, or the area (technological mode) of DBD avalanche development, is within the small air gaps area - \( d < 3 \text{ mm} \), [4].

Experimental studies have been conducted, allowing persistent and successful evaluation of the technical plasma systems created, as shown in Fig. 3.

Fig. 4 shows the relevant family characteristics of magnetically stimulated triode DBD plasma system, revealing the improvement of the studied triode coplanar DBD plasma system in its latest implementation with magnetic stimulation, Fig. 4.
Fig. 4. A family of curves presenting the active power surface density \( p_a \) change caused by air gap \( d \) at constant effective value of the supply voltage \( U \) (RMS) with industrial frequency (50 Hz) in magnetically stimulated triode DBD plasma system with power supplied third electrode and alkali glass dielectric barrier with thickness \( b = 3 \) mm at capacitor capacitance \( C_{\text{add}} \), nF: a - 25, b - 50.

Conclusion

Enhanced half-opened technological plasma systems have been examined, generating chemical active particles intended for indirect plasma-chemical modification of low-energy surfaces.

A significant impact of DBD magnetic stimulation on the discharge technological characteristics and the triode DBD plasma system efficiency improvement has been reported.

Acknowledgment

The financial support of the National Science Fund, Ministry of Education and Science of Bulgaria, for the Research Project DO-02-11: EF/2009 is gratefully acknowledged.

References


