Enhanced dielectric barrier discharge system for plasma surface modification

D. Gospodinova, P. Dineff

Technical University, Sofia, Bulgaria

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.

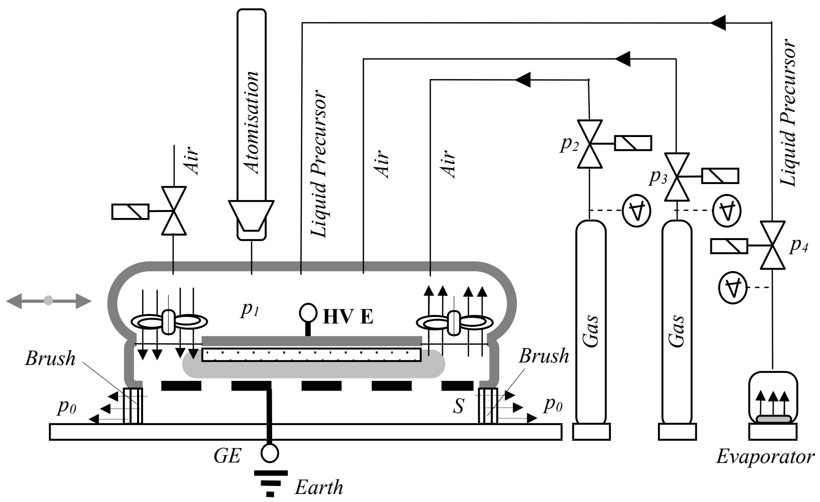

Fig. 1. Half-opened technological diode *DBD*-plasma system (*Peter Dineff*, 2005).

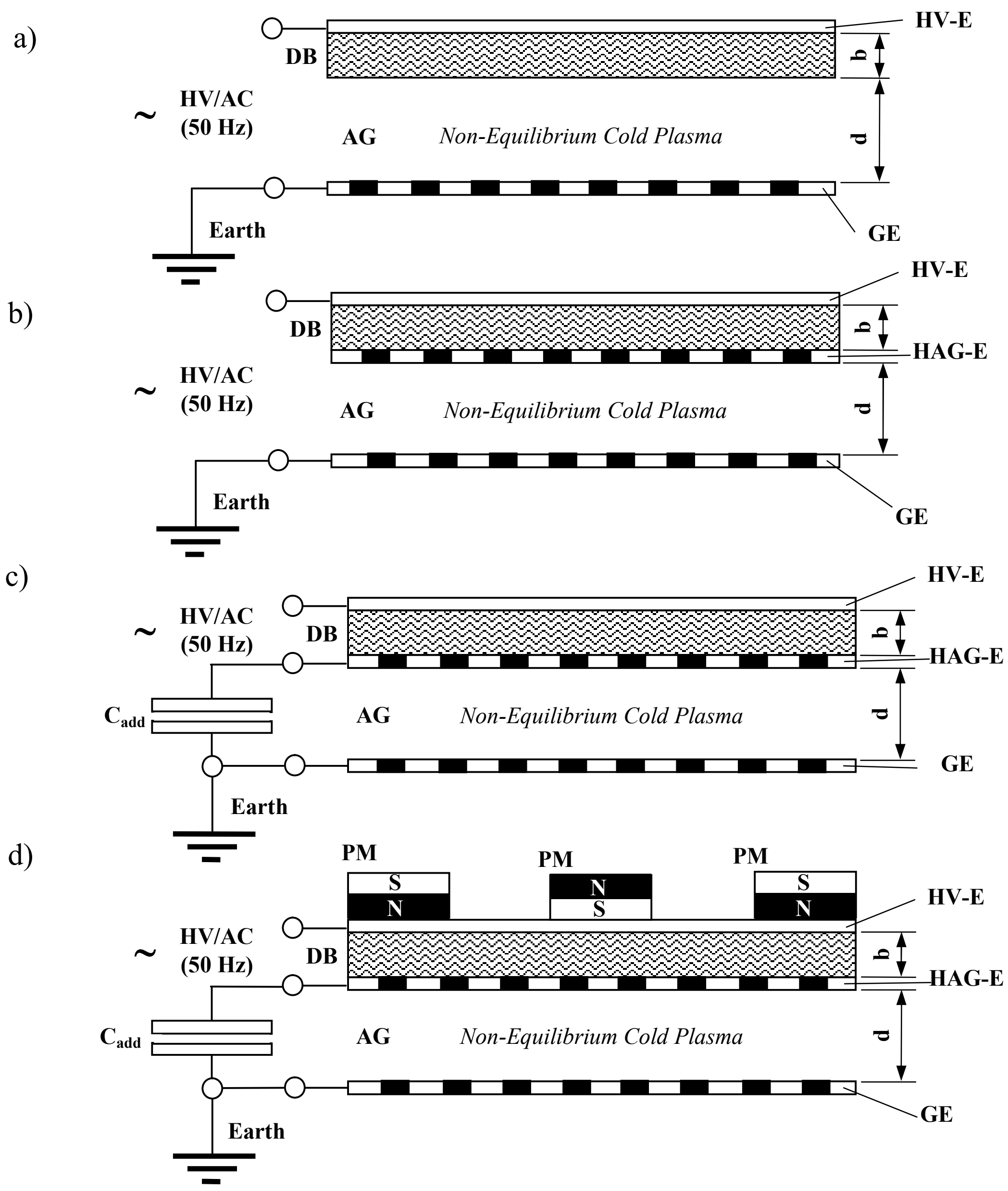

Fig. 2. A schematic presentation of experimentally studied coplanar DBD plasma systems (generator): **a** - diode DBD plasma (basic) system; **b** - triode DBD plasma system with bipolar third electrode; **c** - triode DBD plasma system with power supplied third electrode; **d** - magnetically stimulated triode DBD plasma system with power supplied third electrode:

GE - grounded electrode; ***HAG-E*** - hole array grid electrode; ***HV-E*** - high voltage electrode; ***DB*** - dielectric barrier (alkali glass); C_{add} - capacity of a serial switch on capacitor; ***PM*** - permanent magnet; ***AG*** - air or working gap; ***HV/AC*** (50 Hz) - high voltage power supply.

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 *Dow Corning Plasma Solutions* and *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.

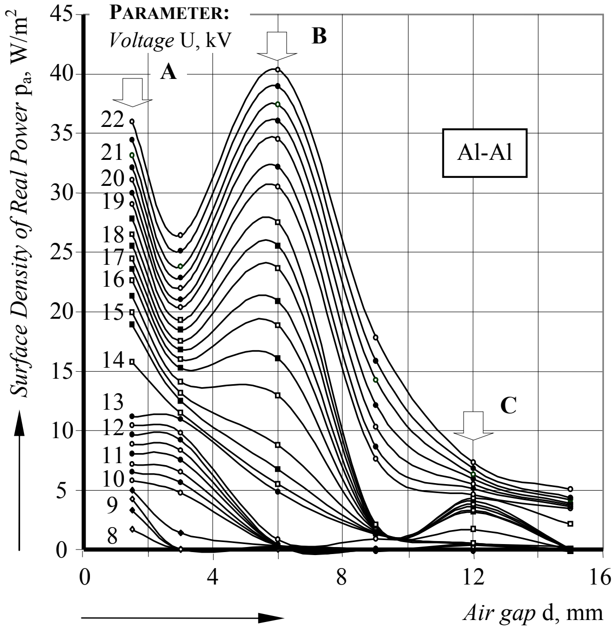

Fig. 3. A family of curves presenting the active power surface density p_a change caused by air (working) gap d at constant effective value of the supply voltage U (RMS) with industrial frequency (50 Hz) in diode DBD plasma (basic) system with non-magnetic electrodes and alkali glass dielectric barrier with thickness b = 3 mm.

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 ($p_R = P_R/S$, where S 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 - $d < 3$ 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.

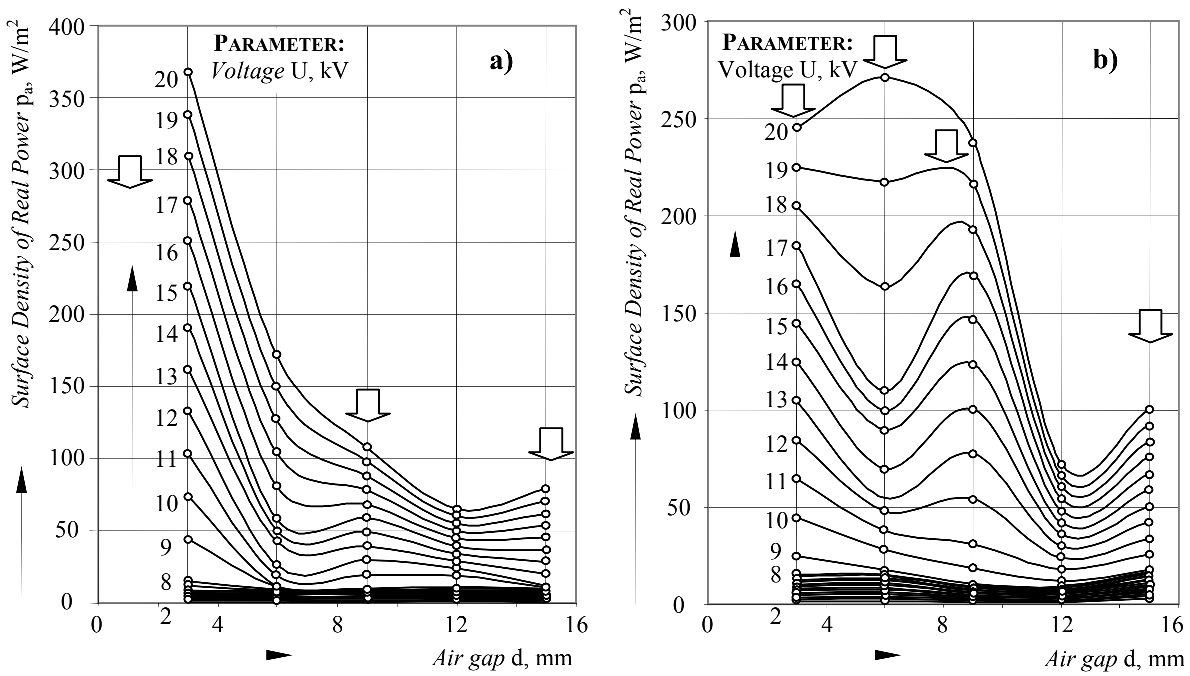

Fig. 4. A family of curves presenting the active power surface density p_a change caused by air gap d at constant effective value of the supply voltage U (RMS) with industrial frequency (50 Hz) in magnetically stimulated triode DBD plasma system with power supplied third electrode and alkali glass dielectric barrier with thickness b = 3 mm at capacitor capacitance C_{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

[1] P. Dineff, L. Kostova, *Method for Plasma Chemical Surface Modification*. H05H 1/24, WO Patent 2006/133524 A2; International Patent Application No.: PCT/BG2006/000012; Priority Date: 14.06.2005 (109189); Publication Date: 21.12. (2006).

[2] P. Dineff, *Industrial Plasma Surface Technologies at Atmospheric Pressure*, Electrical Engineering and Electronics (E+E), Vol. 45, Issue 9÷10, pp. 41÷48 (2010).

[3] P. Dineff, *Homogenous Atmospheric Pressure Discharge*. Annual of Technical University of Sofia, Vol. 59, Issue 2, pp. 146÷155 (2009).

[4] P. Dineff, D. Gospodinova, and M. Shopov, *Plasma Technologies*. Manual for Laboratory Classes. Sofia, Avangard-Prima (2008).