Research of Processes and Devices for Plasma Treatment of Polymeric Films Before Vacuum Coating

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Keywords: Polymer substrate, Morphology, Plasma treatment

ABSTRACT

Processes and devices for vacuum treatment of roll polymeric materials are described. Treatment effectiveness was determined according to adhesion of metal coating to the substrate and according to delaminating force of glued films. Film surface modification after treatment was investigated by the method of atomic power microscopy. It is shown that overlay of additional magnetic field on the glow discharge electrode unit leads to increase of treatment effectiveness and allows to change treatment conditions at a wide range according to character of the polymeric films structure.

INTRODUCTION

Pretreatment of substrate surfaces is necessary when implementing rather complicated processes of plasma deposition methods in modern vacuum equipment.

If glow discharge plasma is used for the pretreatment, it is usually made at pressures 0.01-0.1 torr. For that purpose a separate machinery is used or a special locking unit is built-in into the coater. The present work describes a device allowing to perform treatment processes starting from pressures $3x10^{-3}$ torr and above. This is achieved by overlaying a magnetic field onto the electrode system. Verification of treatment effectiveness for various film materials showed that the treated material may be oriented differently relative the electrode unit and winding speed during treatment can reach 15 m/min.

EXPERIMENT

Different versions of magnetic systems in combination with most common electrode systems of Sidrabe have been tested during the works. The most optimal system is shown in Figure 1.

Dimensions of the electrode system are 100x780 mm (electrode width is 35 mm). Magnetic field induction was 5 mT at the electrode level, when distance between the electrode and magnetic systems was 80 mm.

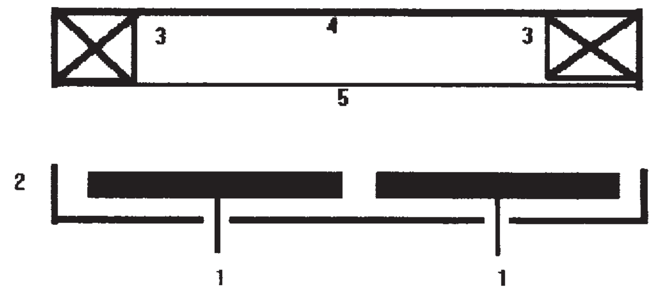

Figure 1. System of electrodes with magnets. 1–electrodes, 2–shield, 3–magnets, 4–magnetic core, 5–shield.

Figure 2a shows distribution of the magnetic lines of force in the plasma zone. Figure 2b shows equipotential surfaces of the electrode system. As it is seen from Figure 2, influence of the magnetic field on the electric field is considerable. It was found experimentally that decrease of the distance between the electrodes and magnets increases discharge current at the same gas pressure.

41st Annual Technical Conference Proceedings (1998) ISSN 0737-5921

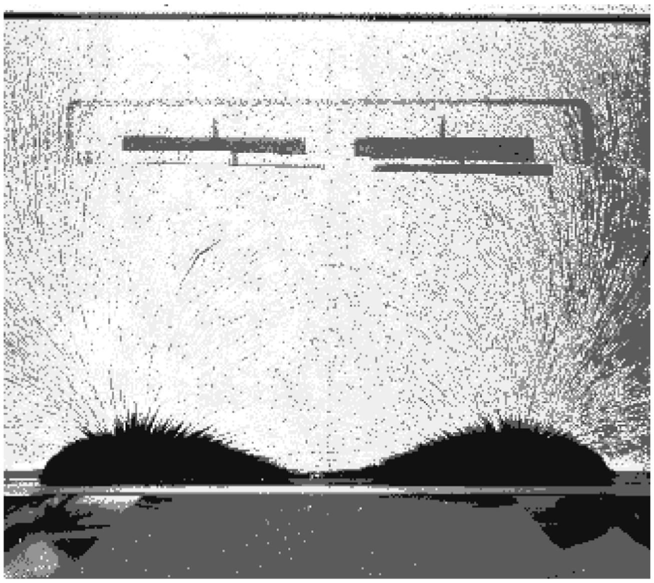

Figure 2a. Distribution of a magnetic field in a discharge gap.

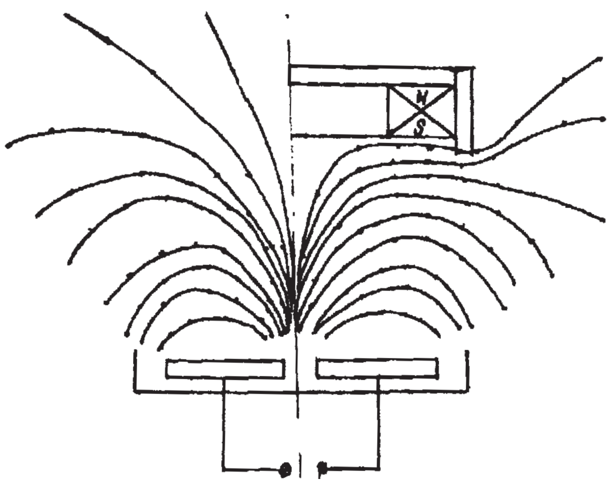

Figure 2b. Cross-section of equipotential surfaces of the systems with and without a magnetic field.

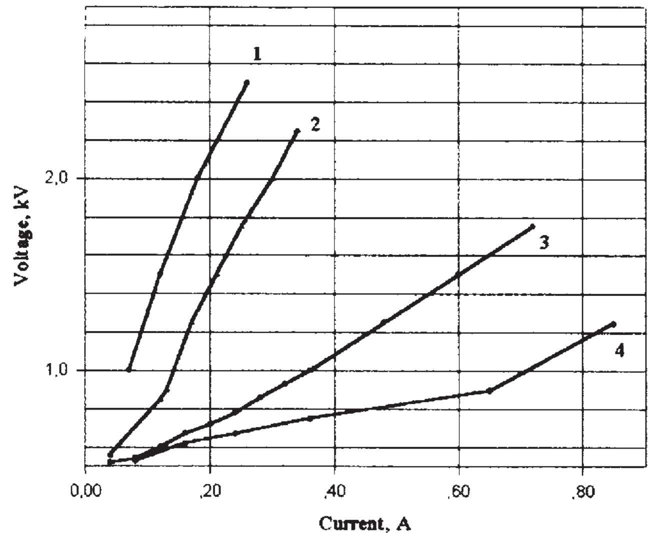

Figure 3. Volt-ampere characteristics of discharge at various pressures: 1 - $3x10^{-3}$ torr; 2 - $5x10^{-3}$ torr; 3 - $1x10^{-2}$ torr; 4 - $2x10^{-2}$ torr.

The offered device can be DC or AC operated. The treated material can be run between the electrodes and magnetic system, at one or two sides of the electrode zone, as it is shown in Figure 4.

Verification of the treatment effectiveness was carried out using the following materials:

PP—polypropylene film, made in Austria;

PMT—double-layer polyimide-fluoroplastic film, made in Russia;

FEP—teflon film, made in USA.

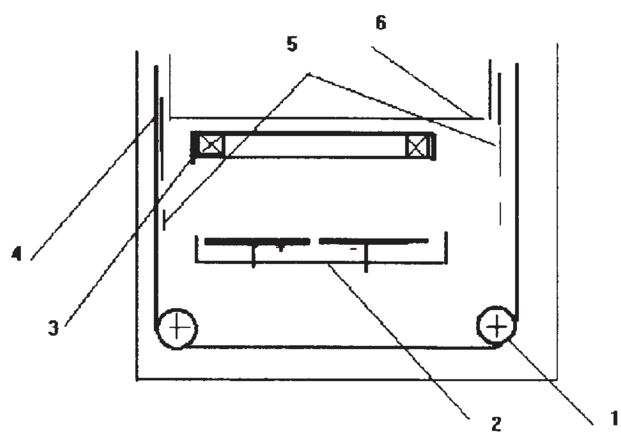

Figure 4. Version of application of the film treatment device.

To estimate treatment effectiveness the following methods were applied:

- measurement of the water wetting angle of the treated surface;
- adhesion estimation of the copper coating, deposited in vacuum onto the treated surface;
- measurement of delaminating force of the surfaces, glow discharge treated and subsequently glued to each other or to the steel plate;
- surface analysis by atomic power microscopy.

Figures 5-8 show relationship between wetting angle and discharge power, allowing for winding speed.

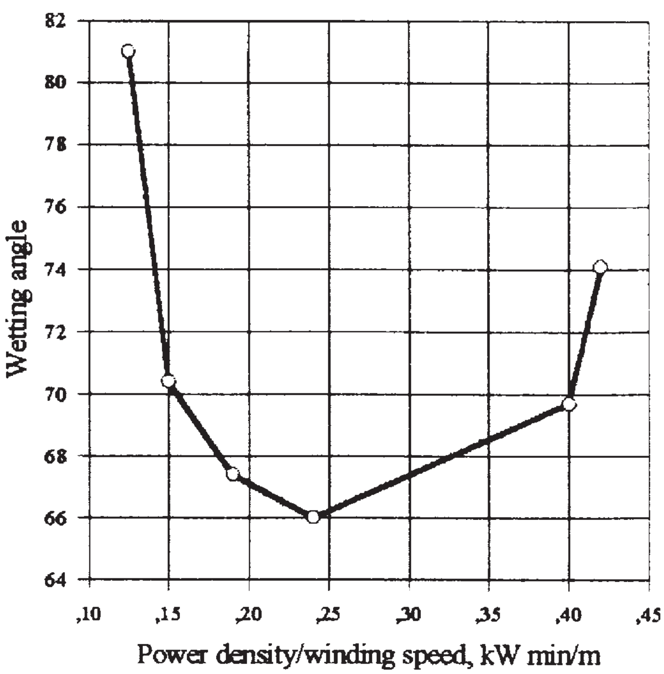

Figure 5. Relationship between wetting angle and treatment power for FEP film.

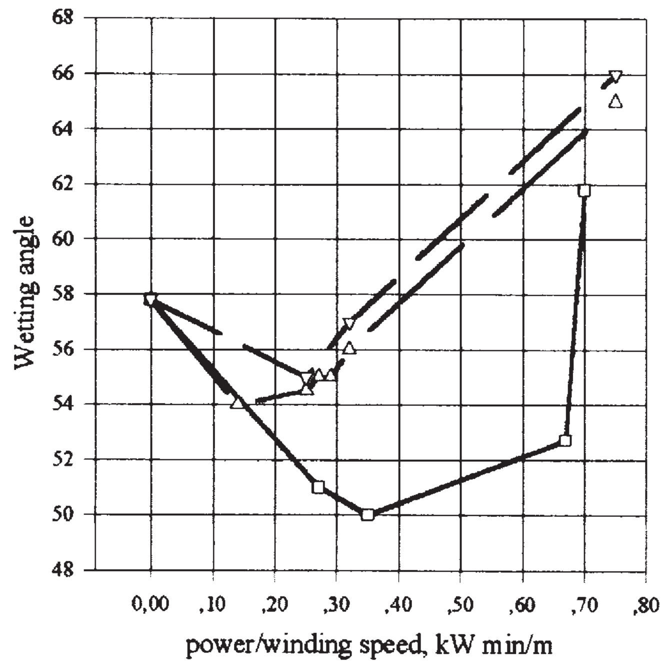

Figure 6. Relationship between wetting angle and treatment power for PI film. Upper curves relate to the film, DC and AC treated between the electrodes and magnetic system. The lower curve relates to the film, placed on one side of the system during treatment.

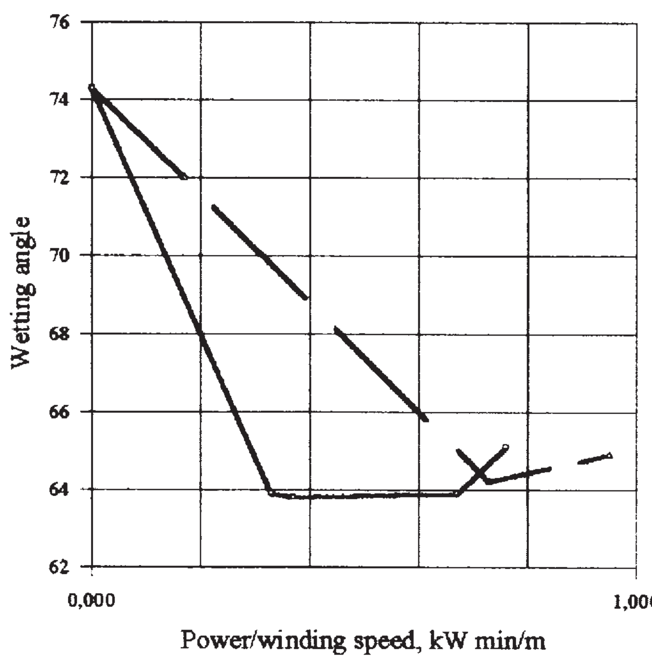

Figure 7. Relationship between the wetting angle and discharge power for teflon. The left curve is for film between the electrodes and magnetic system, the right curve is for the film, placed on one side of the system during treatment.

As it is seen from Figures 6-8, the treated film position relative the device essentially influences the treatment effectiveness. So, when the film is between the electrodes and magnetic system the range of relationship between power and winding speed is more narrow, than at the film position outside the electrode zone. In other words, the first system is more sensitive to changes of treatment conditions.

As it is seen from Figure 6, changing of the wetting angle after treatment of the film between the electrodes and magnetic system practically does not depend on powering the electrodes with DC or AC. In case of the film transportation outside the electrode zone, it is advisable to supply AC if two zones of the device are used, and to supply DC if the film is transported only on one side of the device. As far as wetting angle characterizes adhesion rather ambiguously, we also estimated adhesion of a metal coating and measured delaminating force of various glued films depending on wetting angle.

Copper coating adhesion has been estimated for all types of the films. As a rule, satisfactory adhesion was achieved at minimum wetting angles. Comparative analysis of delaminating force for treated surfaces glued to each other and to the steel was carried out for teflon, PP and PIT films. The results showed that in zones with narrow wetting angle delamination goes directly inside the glue layer, but at increased angle the glue is coming off from the film surface.

For analysis of the modification character of the treated films surfaces by atomic power microscopy a morphology of PI and teflon surfaces of double-layer PIT film was determined. The results are shown in Figures 9, 10.

Two opposite tendencies of these surfaces treatment are found. If the teflon surface becomes more developed due to the glow discharge effect, smoothing of the polyimide side surface is observed after treatment. On the basis of the analysis, treatment units were made for two industrial machines, built at Sidrabe, for treatment and vacuum coating films 600 and 1600 mm wide.

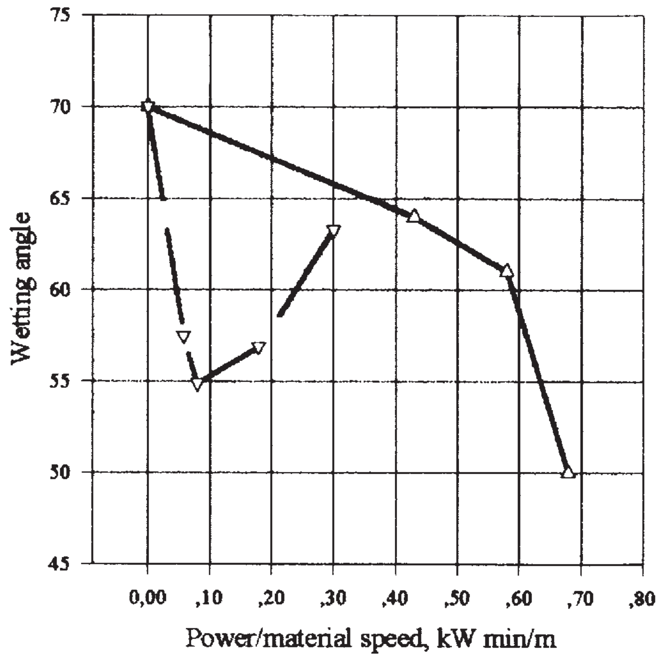

Figure 8. Relationship between the wetting angle and discharge power for PP film. Lower curve isfor the film between the electrodes and magnets, upper curve is for the film, placed on one side of the system during treatment.

CONCLUSION

A unit for glow discharge plasma treatment of roll materials has been developed. This unit can be used in special machines for film activation, as well as in the plasma deposition machines. Winding speed can be up to 15 m/min depending on the treated material. The unit is well compatible with magnetron and electric arc deposition equipment by working pressure and treatment speed. Various film positions relative the unit elements and wide range of pressures and discharge electric parameters allow to change treatment conditions in a wide range and to use it for treatment of different polymeric materials.

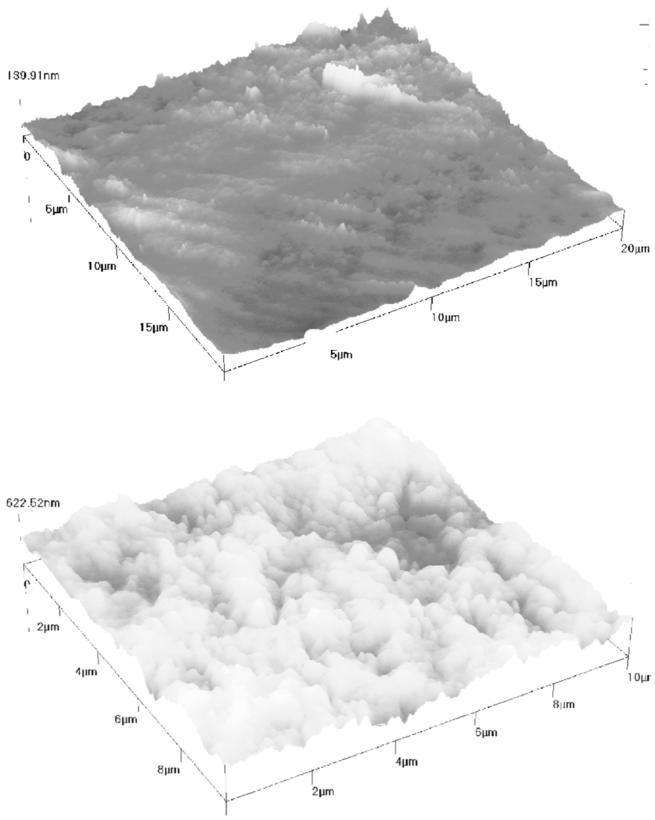

Figure 9. Teflon film surfaces untreated (above) and treated in the glow discharge.

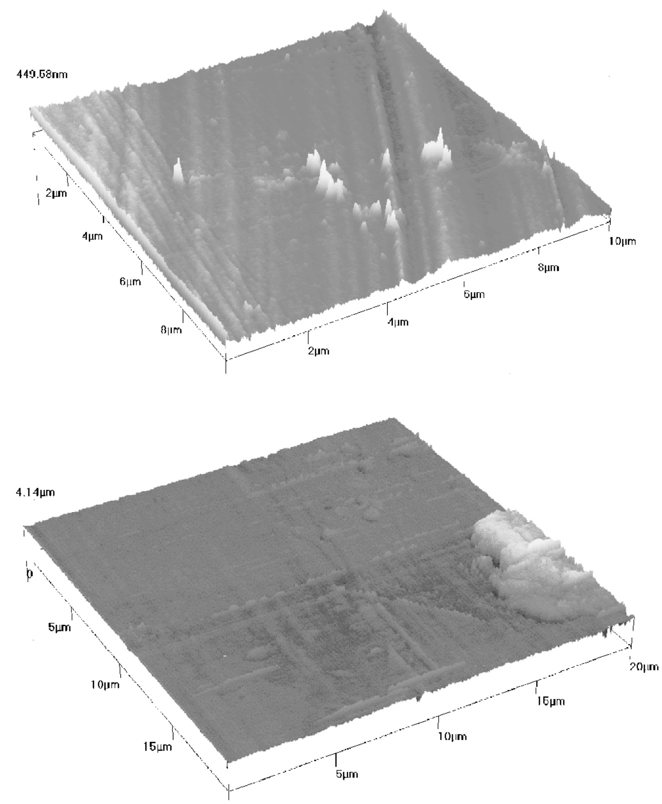

Figure 10. PI film surfaces untreated (above) and treated in the glow discharge.