Principles of In-line System Designing for Protective and Decorative Coating

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ABSTRACT

Considered are the principles of in-line system designing for magnetron coating of 3D articles at reciprocal movement of article carriers (jigs) and article rotation in the plasma treatment and deposition zones. Presented are the research results of plasma treatment efficiency, coating adhesion to the substrate, substrate temperature and physical characteristics of the coating at high-speed introduction of uncoated articles into the line from the atmosphere, short evacuation, plasma treatment and metallization cycles. Magnetrons arrangement was optimized to provide high coating uniformity on 3D articles. A special attention has been paid to designing condensate collection systems for continuous process running during 120 hours.

INTRODUCTION

Basic distinction of an in-line system from a batch-type machine is that articles pump-down, pre-treatment in the glow discharge plasma and deposition time is significantly shorter and articles arrangement geometry relative the sputtering devices is different too. Besides, the in-line systems comprise special vacuum locks that allow maintaining pressure in different compartments at the preset level. Our past experience of building machines for protective and decorative coatings and our laboratory equipment were used to perform initial data analysis, necessary calculations and modeling of a number of units prior to designing the line. Below are presented the work results on some of the design issues.

DEGASSING OF ARTICLES

As it was demonstrated before [1], articles of different plastics have different degassing. Since ground lacquers are often used (depending on the article surface quality) in protective and decorative coatings, degassing of these lacquers should also be taken into account. Figure 1 shows degassing of different plastics both with ground lacquering and without after 20 minutes of evacuation. The same figure demonstrates the growth of degassing when plastics are heated up to 40-45 degrees Celsius. As it is seen from Figure 1 degassing of plastics increases sharply, especially for PA. This should be taken into account when producing coatings during relatively short time. Plastics degassing nature during evacuation is shown in Figure 2 for PP taken as an example.

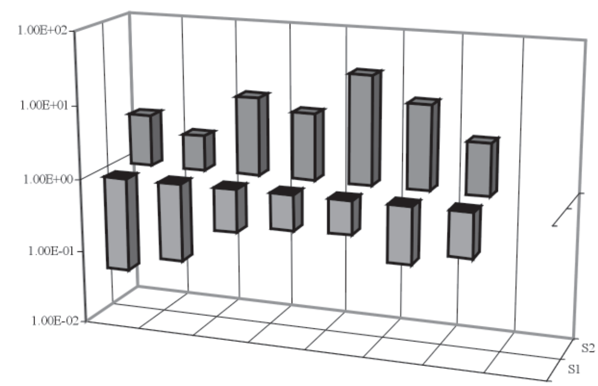

Figure 1. Degassing of various plastics.

First row: 1-PS, 3-ABS, 5-PA, 7-PP, 2,4,6 – the same, but with lacquer coating. Second row: the same, but heated up to 40-450 degrees Celsius.

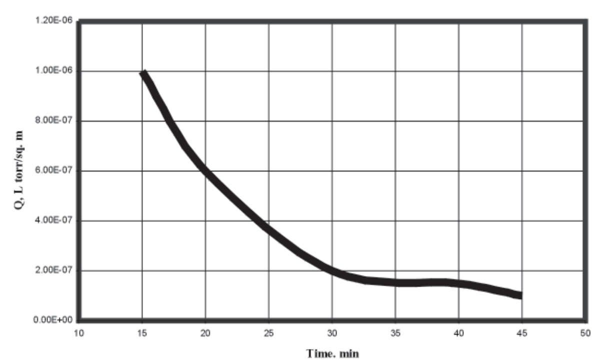

Figure 2. Degassing of PP versus evacuation time

30-50 seconds is the time necessary for articles evacuation in the in-line systems while articles coated in conventional batch-type machines have to be evacuated as long as it takes to pump down the machine. All the gas volume below the curve in Figure 2 should be removed during this period.

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Treatment of articles in the glow discharge plasma promotes faster degassing. Figure 3 shows the change of PP degassing after treatment in the glow discharge plasma.

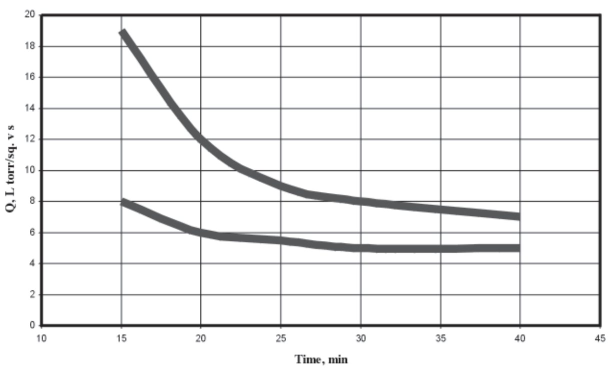

Figure 3. PP degassing before (top curve) and after (lower curve) glow discharge treatment.

As it is seen in Figure 3, glow discharge plasma treatment decreases degassing about 2 times. Based on the data presented, pumping system per individual zones and the length of the way, articles have to go before entering the deposition zone, were calculated.

EFFICIENCY OF ARTICLES TREATMENT IN THE GLOW DISCHARGE PLASMA

During the last few years Sidrabe have designed a number of units for substrate treatment in high-concentration glow discharge plasma, which can be adopted to different evaporation and sputtering systems [2, 3]. In case of the in-line system it is reasonable to use flat electrodes having them installed on chamber walls while articles, rotating relative their axes, are transported on jigs along the electrodes. A possibility of changing discharge parameters is determined by the surface area of electrodes. Figure 4 shows volt-ampere characteristics for electrodes with various areas.

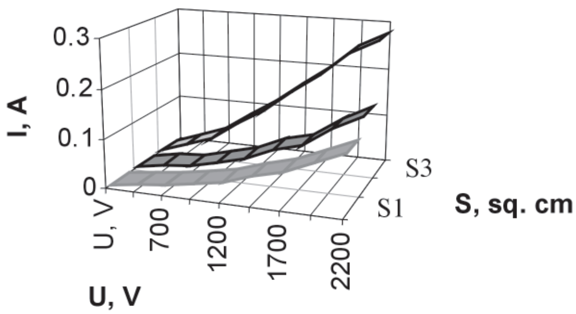

Figure 4. Volt-ampere characteristics of the glow discharge for various electrode areas. P1-150 cm^2, P2-225 cm^2, P3-600 cm^2. Working gas pressure is 0.1 torr.

As it is seen from Figure 4, discharge parameters may be changed in a broad range by varying electrode area and creating optimal treatment conditions for various types of plastic [3].

Since reduction of the electrode length is not always possible, that may decrease the necessary treatment zone length, it is preferable to decrease electrode width so providing the required plasma density. If the articles are too high, two couples of electrodes, powered from individual power supplies, could be installed. The tests on the laboratory machines have demonstrated high treatment efficiency of plastic surfaces during 25-30 seconds while using a high-voltage commercial frequency transformer as a power supply.

MAGNETRON CONFIGURATION

The main purpose of magnetrons in the in-line system is to provide the required coating thickness on 3D articles within a limited period of time while articles are passing the deposition zone, and the articles must not be overheated. This is reached by selecting linear target dimensions, number of targets and their arrangement relative the jigs with articles. Certain assortment of parts to be coated should be stipulated for the in-line system. A sputtering device version, including 2 couples of targets, installed in series and tilted relative each other (Figure 5) is considered. In this case magnetron angle can be changed depending on height and shape of the articles being coated.

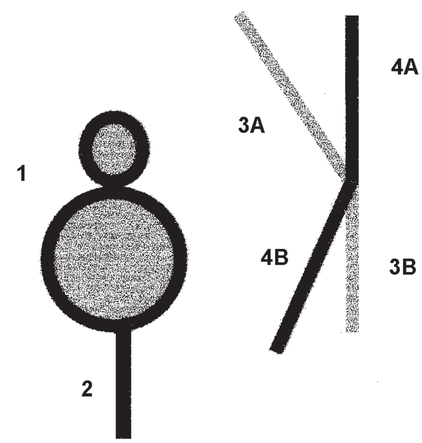

Figure 5. Magnetrons installed under an angle relative each other and the articles. 1-sample, 2-substrate holder, 3A, 3B- first couple of magnetrons, 4A, 4B- second couple of magnetrons.

This sputtering system is rather flexible and allows coating a broad variety of products changing independently the angle between each couple of targets and setting certain power for each target.

PROCESS MODELING ON THE LABORATORY MACHINES AND TESTING THE SAMPLES

To test any of the technical solutions we used different laboratory machines adjusted for specific tasks. So, for simulation of the whole in-line process a batch-type machine, equipped with a fast lock (samples can be introduced into high vacuum zone in 10-15 seconds) was used. Articles were pretreated by plasma and coated by magnetron sputtering in a boost mode. After coating, the parts were taken to standard adhesion (coating adhesion to the substrate), optical and mechanical and climatic tests. Various plastic samples both with and without ground lacquer coating have been tested. Time periods for samples introduction into the vacuum volume, treatment in the activation and deposition zones were checked as it had been assumed for the in-line system. Glow discharge and metal deposition power density were tested too. All the samples had passed standard tests, which have proven that the selected concept of the in-line system was correct.

Another laboratory machine was used for modeling individual units and devices of the future system. A special dummy (in scale 1:5) was created to test and adjust the vacuum locks. This dummy was without any rubber-sealed or other gate valves. The tests demonstrated high reliability of the lock system during 120 hours of continuous operation.

CONDENSATE COLLECTION

One of the serious problems in the in-line is collection of condensate that was not deposited on articles. There are various ways to solving this problem. Using hot shields is not reasonable in this case, since they will create extra heating of articles, which is not desirable. Application of chilled shields stimulating condensate collection into special bunkers appears to be quite complicated, especially after venting the chamber for collecting condensate during maintenance works.

A search was made to find materials providing good adhesion of metal coating with high (up to 100 microns and more) thickness. In the result glass fabric was selected as a material for this purpose. The experiments have demonstrated that more than 200 microns of aluminum can be deposited on the glass fabric during continuous sputtering cycle. In this case the layer is cracking, but not delaminating from the fabric. Even at boost sputtering aluminum, deposited on the fabric, would melt, flow down and cure on a less heated part of the fabric, again without dripping or delaminating from it. Figure 6 shows a glass fabric sample coated with 200-micron aluminum. Traces of melted metal are visible in the center.

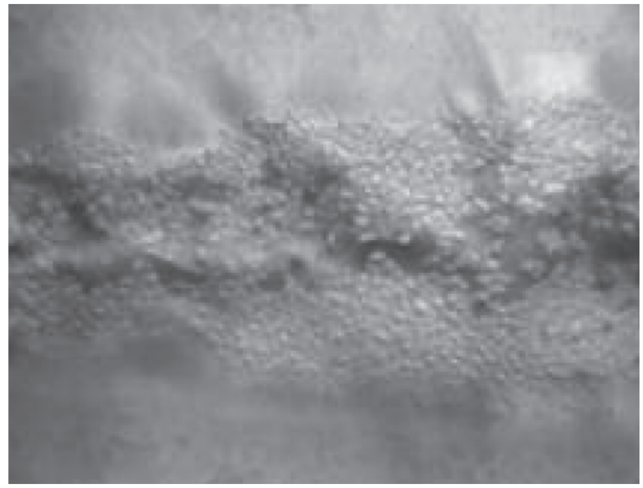

Figure 6. Aluminum condensate (200 micron) on the glass fabric.

According to the test results glass fabric has been selected as a construction material that sorbs condensate in the deposition zone of the industrial machine.

Based on the performed tests and modeling the industrial in-line system was built. Currently the system is operating successfully at the Customer's facility.

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