A Plasma System for Low-Emissive Coating Deposition

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Abstract – Plasma Systems "Opal" were worked out by us for deposition of thin films with various composition on the surface of sheet glass, plastic and other materials. The deposition of films is fulfilled with assistance of magnetron discharge plasma. The system "Opal-3" is presented in the paper. Its basic working elements and a technological regime for deposition of heat-reflecting (low-emissive) coating on a basis of Ag are described.

Introduction

Plasma system "Opal-3" is described in the paper. It is destined for modification of sheet glass optic properties by means of making heat-reflecting (low-emissive) coating on the surface and for deposition thin films of various composition on the surface of plastic and other materials.

"Opal" Systems are the class of machines, which have as working parts vertically set planar magnetrons on direct current and ion sources with the confined electron drift [1], which are the means of cleaning the glass surface before deposition of coating.

Treated sheets of glass are placed by pairs into vertical substrate, which makes back-and-forth motion in vacuum along working parts of the system in according to prescribed technical regime. Its speed may be changed in dependence on coating parameters. As glass moves the modifying coating is depositing on its surface.

"Opal" Systems are fulfilled according to a modular principle and consist of elements quantity and placement of which may changed in dependence on a type of produced output and requirements to productivity.

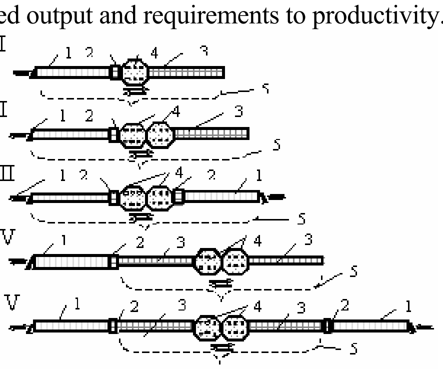

Fig. 1. Variants of the "Opal" System integration: I – loading chamber; II – gate; III – turning chamber; IV – working chamber; V – travel zone of substrate with glass under treatment

The variants of the "Opal" System configuration are presented in Fig. 1.

The basic working elements and components of the "Opal-3" System (variant IV) are described briefly in this paper. The general view of it (with auxiliary equipment) is shown in Fig. 2.

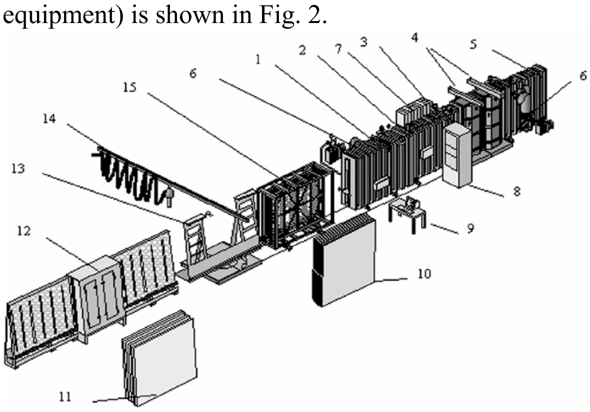

Fig. 2. Processing line on the base of the "Opal-3" System: 1 – loading chamber; 2 – gate; 3 – turning chamber I; 4 – working chamber; 5 – turning chamber II; 6 – diffusion pumps; 7 – power suppliers; 8 – control panel; 9 – operator working place; 10 – sheet glass after treatment; 11 – sheet glass before treatment; 12 – washing machine; 13 – turn arrangement; 14 – hoisting appliance; 15 – substrate for sheet glass

2. Vacuum System and Frame Elements

Total volume of the "Opal-3" System which must be under vacuum is 6 m^3, surface area of frame elements is about 80 m^2. Vacuum system contains pumps, piping, gates, valves, sensors of pressure.

3. Ion Sources

Ion sources with confined electron drift are fulfilled as rectangle boxes with magnets and anodes inside. Anodes are cooled by water [1]. Working gas (argon usually) is given inside. Then, ion sources inject this gas to supply work of magnetrons.

Two extensive ion sources are situated in first working chamber (Fig. 3). They are assigned to produce a high energy ion flow of argon, oxygen and other gases. This ion flow cleans the surface of treated material (glass). As a result of such cleaning, the adsorbed atoms, moisture films and other pollutions which negatively influence adhesion of deposited material and glass are moved off the surface.

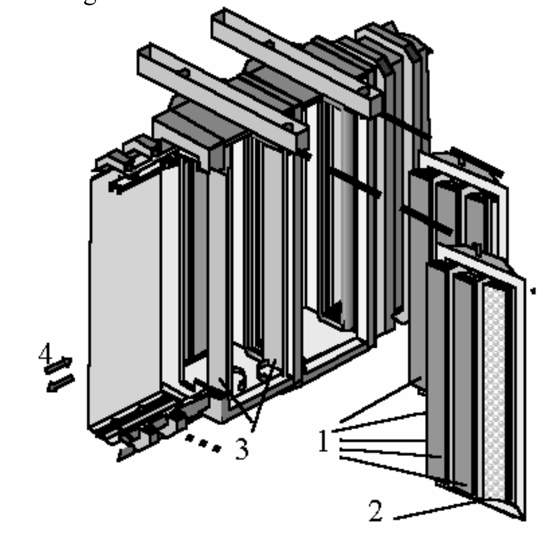

Fig. 3. Working chambers: 1 – magnetron; 2 – power supplier; 3 – shield; 4 – sheet glass

Sometimes ion treatment is useful for activation of chemical binding on the surface which assists to improve adhesion and stabilization of films.

4. Magnetrons

Modifying coating is deposited with assist of magnetron discharge plasma.

Planar type magnetrons are made as extensive rectangles and are hanged vertically in working chambers. Targets of 2500×(90...110)×8 mm^3 size have direct cooling and are attached to frame by screws. The magnet system on a base of ferrite magnets is situated inside frame.

Power suppliers of magnetrons have following parameters:

maximal output voltage is 700 V;

maximal output current is 40 A;

maximal output power is 20 kW;

time of protection response on short circuit is not more then 2 μs;

precision of current or voltage stabilization is not worse then 1%.

It's made provision for control both manual regime and by means of a personal computer through an interface RS-485.

It's possible to use cylindrical magnetrons [2], magnetrons with additional magnets to improve space distribution of thickness of deposited coating [3], magnetrons with anodes supplied with injection holes [4] and so on.

5. Gas Supply System

Stability of magnetron work depends substantially on permanency of gas environment in working chamber. The conditions for uniform gas supplying to magnetrons are produced in "Opal" Systems. At that ion sources are used as injectors and gas flow controllers type of MKS-1179 serve as an executive mechanism.

6. Control System

The System is provided with automatic control system on a base of programmed logical controllers and a personal computer. The computer visualizes technological process, supplies an operator with convenient interface of parameter control, records regimes of operation performance, contains reference materials, instructions and other documents regulating its operation, maintenance and repair.

System characteristics are presented in Table 1.

Table 1. Technical characteristics of the "Opal-3" System

Characteristic name	Values
Maximal size of glass sheet, m	2.134×3.050
A number of magnetrons, units	10
A number of ion source, units	2
Quantity of simultaneously treated glass sheets, units	2
Speed of motion of substrate with glass, mm/s	2–80
Maximal residual gas pressure, Pa	$6 \cdot 10^{-3}$
Working length of magnetrons, mm	2500
Sample of deposited heat-reflecting coating composition	TiO_2 (or SnO_2) – (NiCr) – Ag – (NiCr) – TiO_2 (or SnO_2)
Productivity at deposition of heat-reflecting coating, m^2/hour	15–30 (in dependence on coating type)
Productivity at deposition of toning coating, m^2/hour	30–60 (in dependence on coating type)
Consumption of working gas, liter/hour	60
Voltage of ion source power supplier	1–3.5 kV
Ion source current	0.1–2.0 A
Voltage of magnetron power supplier	150–600 V
Magnetron current	1.0–40 A
Maximal consumable power, kW	150
A number of rotary vacuum pumps with productivity of 69 liter/s	4
Occupied area, m^2	200

7. System Operation in Technological Regime

As an example we describe operation of the "Opal-3" System in technological regime to deposit on glass a heat-reflecting (low-emissive) coating with one functional layer Ag. Such coating is applied extensively by world-wide top-level firms producing glass with heat-reflecting coating and have become classical at present. The coating consists of five layers: glass – TiO_2 – NiCr – Ag – NiCr – TiO_2. The thickness in nanometers of corresponding layers is: 32; 1; 11; 1; 36.

The deposition is conducted under automatic regime and is organized to have possibility while all process to check thickness of layers responsible for glass operating characteristics: TiO_2 and Ag. While all technological process operator controls the parameters of layers and compares with basic values. In the case of deviation of layer thickness more than 3% he makes correction into deposition regime of next glass.

The process begins with TiO_2 deposition. The work regime of magnetrons is fitted so that required thickness of TiO_2 film (32 nm) is reached in even quantity of substrate passing. At the same time it has possibility to control the signal from glass before deposition (Fig. 4, point 1) and after finish of deposition of corresponding layers (Fig. 4, points 2, 3, 4).

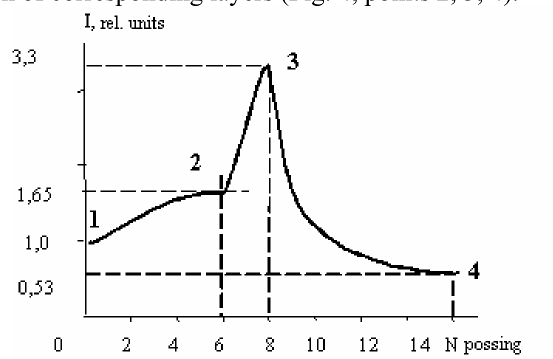

Fig. 4. Dependence on quantity of passing of the signal reflected from the glass sample when depositing five-layer heat-reflecting coating, where: 1 – reflection from initial glass; 2 – after deposition of the TiO_2 layer of 32 nm thickness; 3 – after additional deposition of the NiCr layer of 1 nm thickness and the Ag layer of 11 nm; 4 – after additional deposition of the NiCr layer of 1 nm thickness and the TiO_2 layer of 32 nm thickness

When TiO_2 layer deposition has been completed magnetrons with Ti-cathodes turn off automatically, Ar and O_2 gas supply valves close and pause (≈ 30 s) is kept to pump out residual gases from the chamber. Then magnetrons with NiCr cathodes are turned on according to the program.

Training of NiCr cathodes is realized during 20 s according to the program of engaging. Then deposition of NiCr layer is carried out. At the same time the substrate with glass moves towards a turning chamber (the chamber where substrate with glass changes its direction of moving on opposite).

Deposition of the Ag layer is fulfilled by similar algorithm, the substrate with glass moves towards the loading chamber.

When the substrate with glass has got the sensor of location inside the loading chamber the measurement of the signal from glass occurs (point 3, Fig. 4), at that the signal must overtop in 3.3 times initial reflection from glass.

Deposition of the outer NiCr layer is no different from deposition of analogous inner one.

The feature of outer TiO_2 layer is that depositing stops when getting minimal reflection from glass (control of the reflected signal is fulfilled at λ= 1.40 nm).

Deposited glass has transmission ≈ 82...84% in visible region and reflection ≈ 91% in infra-red region (λ = 10 μm). Heat resistance of double-glazed window with such glass is about 0.63 m^2°C/W.

References

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