Formation of the hydrophobic coating on polymeric textile materials in nonequilibrium low-temperature plasma

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Abstract. The use of low-temperature plasma for drawing a hydrophobic coating among argon-acetylene (70:30) on polyether textile materials is investigated in work. As a result of the modification, a granular coating with a thickness of 5–10 μm is formed. This hydrophobic covering has allowed to increase values of a contact angle of wetting to 138 degrees.

1. The Introduction
Modification by drawing hydrocarbonic coatings 0.01–50 microns thick in the conditions of nonequilibrium low-temperature plasma (NLTP) with the set structure, chemical and physic-mechanical properties which allows to hydrofobisate the surface of textile materials was widely adopted. Such coatings allow to change significantly mechanical, hygienic and operational properties of initial material.

The most widespread methods of receiving volume hydrocarbonic plasma is use smoldering, radio frequency (RF) and microwave of discharges and their modifications. Advantages of RF of the discharge are: a possibility of drawing hydrocarbonic coatings on dielectric substrates, high concentration of plasma (10×10 cm⁻³) and smaller working pressure (0.1–100 mTorr), in comparison with the glow discharge.[1].

In this regard the possibility of formation of a hydrophobic coating on the surface of polyester textile materials when processing in nonequilibrium low-temperature plasma is considered in this work.

2. Materials, methods and equipment
As objects of a research the textile is used art. 80304 Climate 150 RS, 100% polyether. It has a polyurethane membrane coating Climate 3 and oil–repellent impregnation and textile (art. 87015 Climate 260, 78% polyether, 22% viscose) with a polyurethane membrane coating Climate 3+, a polyurethane lining and water-repellent impregnation of production of LLC «Tchaikovsky Textiles».
Modification was carried out in the experimental radio frequency capacitive (RFC) plasma generator, description explicitly of which is provided in operation [2]. The mode of plasma modification was regulated by change of parameters in the following limits: the expenditure of gas (G) of 0–0.04 g/s with, tension on the anode of the oscillator tube (U_a) of 5–7 kV, working pressure in the working camera (P) of 21–27 Pa; frequency of the generator (f) is 13.56 MHz, a processing time (τ) 1–10 min. As plasma-forming gas the compound of argon and acetylene in the ratio 70:30 was used.

Coating of polyester textile materials was created on the surface of plasma argon–acetylene (70:30) after modification. For visualization of the created coating on the surface of f textiles, the research of surface morphology and cross sections of the studied materials by means of the confocal laser scanning 3D microscope of Olympus LEXT OLS 4100 was conducted [3].

Influence of the hydrocarbonic coating received by means of plasma modification on hydrophilic and hydrophobic properties of the chosen fabrics was investigated with the help of method "lying drop" on the Kruss Easy Drop DSA 20E device [4].

Hygienic properties after RFC-plasma modifications of polyester textile materials were estimated in parameters of vapor permeability (GOST 22900–78), air permeability on the A0002D Digital device of production IDM Instruments according to the ASTM D737 standard and water resistance on the FX 3000 HYDROTESTER III device of production of Textest AG according to the EN 20811-1992 standard [5–10].

3. Results
Results of confocal microscopy (CM) of the created hydrophobic coating on textile art. 80304 Climate 150 RS are presented in Fig. 1.

On the basis of results of microscopy (Fig. 1), it is possible to draw a conclusion that after modification in nonequilibrium plasma on the surface of fibers of textiles art. 80304 Climate 150 RS and art. 87015 Climate 260 the granular coating (Fig. 1 b and d) was formed out of acetylene polymerization products. Thickness of this coating was estimated according to micro photos of cross sections (Fig. 1 g and h) was also 5–10 microns.

![Figure 1. CM images (×100) of surfaces before (a, c) and after (b, d) modification in NLTP and cuts before (e, f) and after (g, h) modification in NLTP of textile fibers art. 80304 Climate 150 RS pictures (a, b, e, f) and art. 87015 Climate 260 in pictures (c, d, g, h)](image)

Contact angle of wetting textile surfaces art. 80304 Climate 150 RS and textiles art. 87015 Climates 260 was measured for change research superficial and hygienic properties of the studied
materials after formation of a hydrophobic coating in low-temperature plasma. Also the vapor permeability, water absorption, air permeability and water resistance was measured. Results of a research are presented in table 1.

Apparent effect of a hydrophobization of a surface of the studied materials increase at modification in plasma of argon–acetylene (70:30). It comes from the results given in table 1. The value of contact angle of wetting after plasma modification increases by 37.1% for textile art. 80304 Climate 150 RS and for 41.0% of textile art. 87015 Climate 260.

Results of a research of hygienic properties of textile materials after formation of a hydrophobic coating demonstrate that there is an increase in their water absorption by 17% and more. Also it should be noted that after formation of a coating on the surfaces of textiles, there is an insignificant decrease in their vapor- and air permeability. Fabric water absorption decreases considerably art 80304 Climate 150 RS – for 28.6%, where as textile water absorption art. 87015 Climate 260 doesn’t change. Decrease in values of parameter of water absorption can have an adverse effect on the term of operation of products from such textiles.

**Table 1. Values of hygienic properties of textile polyester materials before and after plasma hydrophobization**

| Parameter                      | Sample       | Textile art. 80304 Climate 150 RS | Textile art. 87015 Climate 260 |
|-------------------------------|--------------|-----------------------------------|---------------------------------|
| Contact angle of wetting, degree | Control 97   | 98                                | 98                              |
|                               | Modification 133 | 138                              | 138                             |
| Water resistance, mbar        | Control 981  | > 1000                            | > 1000                          |
|                               | Modification > 1000 | > 1000                          | > 1000                          |
| Vapour permeability, g/m² in 24 hours | Control 1740 | 2500                              | 2497                            |
|                               | Modification 1739 | 2497                          | 2497                            |
| Water absorption, %           | Control 1.4   | 0.6                               | 0.6                             |
|                               | Modification 0.4 | 0.6                          | 0.6                             |
| Air permeability, mm/s        | Control 2.6   | 5.2                               | 5.2                             |
|                               | Modification 2.5 | 5.2                          | 5.2                             |

4. Conclusions

Thus, as a result of the conducted researches on formation of a hydrocarbonic coating on the surface of textiles art. 80304 Climate 150 RS and art. 87015 Climate 260, it is possible to draw the following conclusions:

1. The created hydrocarbonic coating out of products argon–acetylene plasma has uneven granular character at a thickness of 5–10 microns.
2. The value of a contact angle of wetting of textiles after modifications on NLTP increases to the 138 degrees.
3. Influence of the created hydrocarbonic coating on hygienic properties of polyester textile materials has positive effect which was shown in values of water resistance increase.

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