Modification of a surface of synthetic fibrous materials by silver nanoparticles with application of plasma processing

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Abstract. Results of experimental researches on modification of textile polypropylene fibrous materials by a solution of silver nanoparticles with application of plasma processing are presented. Processing of fibrous materials by a current of nonequilibrium low-temperature plasma allows to apply effectively on materials antibacterial preparation and to fix nanoparticles of silver in a superficial layer of a material.

1. The Introduction
The use of impregnation of woven and non-woven synthetic materials by silver nanoparticles makes it possible to receive textile materials with bactericidal properties. High antibacterial activity of silver nanoparticles, a full range of antimicrobial action, as well as the suppression of pathogenic microflora make irreplaceable data modified textile materials for the production of textiles for medical purposes: medical wear and linens, both reusable and disposable use; Disposable surgical clothes and underwear; As well as medical disposable personal protective equipment. Thus, the need for production of high-quality textile materials of special purpose with high hygienic characteristics, as well as antimicrobial and antistatic properties, determines the urgency of development this topic.

Modification of textile materials by silver nanoparticles with application of plasma processing, unlike other technologies, gives an opportunity to receive textile materials, possessing not only various bactericidal properties, but also high hydrophilic, in particular the ability to absorb sweat, which is an important hygienic indicator and especially relevant for materials from synthetic fibers, which are hydrophobic. Plasma processing gives an opportunity to receive nanomodified textiles of a full spectrum of antimicrobial action, while there is no destroy influence on materials of processed products, and technology of plasma processing is environmentally safe. Plasma processing of high-frequency capacitive discharge, gives the possibility of obtaining textile materials with antibacterial properties resistant in time (prevents the particle entrainment from the surface of the material during wash and operation).

2. Materials, methods and equipment
For modification of textile polypropylene materials the experimental high-frequency plasma installation of the capacitive discharge of low pressure was used.
To evaluate the results of modification of materials by nanoparticles of silver with the use of low-temperature plasma processing is important quantitative analysis of changes in their properties. Property parameters were defined under normal conditions. The research used standard and special methods. The contact angle, characterizing the degree of wetting material, was determined on the device Kruss Easy drop DSA 20E of the sitting drop's method. The time of drop spreading on the surface of the material is determined by means of a stopwatch and is counted from falling drop on the surface of the material until it is completely absorbed by the material. Influence of efficiency of processing of materials impregnated with a solution of nanoparticles of silver, low-temperature plasma on durability of fastening of silver nanoparticles in a superficial layer of materials was investigated by determination of quantity of the silver contained in the sample before and after cycle of gas sterilization of specimens. The amount of silver contained in each sample was determined by the atomic emission analysis method on the atomic emission spectrometer ICAP 6300 DUO.

3. Results
In order to establish the patterns of impact of low-temperature plasma on samples of materials, their processing was carried out when changing the input parameters of the installation in the following limits: the discharge power - from 0.4 to 2.2 kW, processing time - from 60 to 600 seconds, the flow of plasma gas - from 0 to 0.06 gram - second (g/s) and pressure in the working chamber - from 13.3 to 30 Pa. From previous researches [1] it follows that for low-temperature plasma processing of capillary-porous and fibrous materials the optimum value of pressure in the working chamber is 26.6 Pa, consumption of plasma gas – 0.04, g/s. At these parameters of plasma the necessary energy of ions is provided, which allows the ions of plasma gas to be introduced into the surface area of the modified samples, which leads to a change of surface properties of materials, which allows to provide the maximum energy and intensity of the ion flow required for modification, but not leading to destructive processes.

The experimental estimation of change of values of an angle of capillarity of fibrous polypropylene fiber processed in optimum modes, depending on structure of plasma gas is carried out. The obtained experimental data are presented in the table.

| Plasma treatment mode   | Plasma forming environment | Angle of wetting (θ), degree | The time of the spreading, second |
|-------------------------|----------------------------|------------------------------|---------------------------------|
| No processing           | –                          | 118                          | -                               |
| W = 1.6 kW; τ = 180 sec.| Argon                      | 35                           | 10                              |
| W = 1.6 kW; τ = 180 sec.| Argon - Air 70:30          | 36                           | 12                              |
| W = 1.4 kW; τ = 180 sec.| Argon - nitrogen 70:30     | 0                            | 0                               |
| W = 1.4 kW; τ = 180 sec.| Air                        | 36                           | 10                              |

The greatest increase of wetability for polypropylene fibrous material is observed in the treatment of argon - nitrogen in the mixture of gases in the ratio of 70:30, respectively. After low-temperature plasma modification there is an instant absorption of a drop on the surface of the material.

To research the influence of plasma modification on the efficiency of fastening of silver nanoparticles in the surface layer of fibrous materials determined the amount of elemental silver on the surface of samples before and after the cycle of gas sterilization. Analysis of previous researches [1] has shown that for fastening of silver nanoparticles in a superficial layer of textile fibers the optimum
plasma forming environment for plasma modification is a mixture of gases argon propane-butane in the ratio of 70:30, respectively. Repeated processing by plasma leads to additional "pounding" of nanoparticles into the surface of materials due to ion bombardment, which promotes physical adsorption of silver nanoparticles in the surface layers, and to formation of superficial grids, due to the presence of propane - butane, capable in an ionized state to interact with formed by ion bombardment free radicals in the surface layer of fiber polymers.

The search for optimal parameters of processing of knitted and non-woven fibrous materials by high-frequency capacitive discharge plasma of low pressure was carried out by varying the power of discharge and the duration of processing plasma modification. The optimum mode of processing of materials modified by nanoparticles of silver, which leads to steady fixing of nanoparticles of silver in a surface layer of these materials is experimentally established: \( Wp = 1.4 \, \text{kW} \), \( t = 180 \, \text{s} \), \( P = 26.6 \, \text{pa} \), \( G = 0.04 \, \text{g/s} \). Plasma forming environment - a mixture of gases argon propane-butane in the ratio of 70:30, respectively. Processing of polypropylene materials modified by nanoparticles low-temperature plasma prevents silver nanoparticles washing out from the surface of fibers in the course of their exploitation of the preoperational gas sterilization, whereas with the unprocessed plasma Samples after the gas sterilization cycle, the amount of silver on the material surface decreases by 18%.

4. Conclusions
The results of the research showed that the effect of plasma modification depends on the composition of plasma-supporting gas, as well as the technological modes of plasma modification. Plasma modification of textile fibrous materials occurs mainly due to the kinetic impact of the flow of ions, due to the formation of the plasma layer of positive charge around the area sample [2], recombination of ions on the surface of the fibers and the effects of the flow of heat.

Application of silver nanoparticles on a surface of polypropylene fibrous materials and subsequent processing of materials in low - temperature plasma in plasma forming mixture of gases argon-propane-butane leads to steady consolidation of silver nanoparticles on a surface of fibers, as evidenced of atomic emission analysis of samples. In this case, the functional purpose of plasma is to activate nanoparticles of silver, the removal of poorly adsorbed and the strengthening of well adsorbed nanoparticles on the surface of materials. The interaction of free radicals on the surface of fibrous materials with plasma gas monomer unit (argon-propane-butane) leads to the formation of surface mesh and smoothing surface of specimens.

References
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