Modification of surface of textile materials with silver nanoparticles in the radio-frequency induction plasma discharge of low pressure

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Abstract. The results of experimental researches on the modification of knitted polyester materials with a solution of silver nanoparticles using radio-frequency induction plasma treatment are presented. The uniformity of application of the antibacterial preparation on the surface of textiles, as well as the effectiveness of fixing silver nanoparticles in the surface layer of the material were investigated.

1. The Introduction
Presently the actual direction in development of the textile industry is development of the knitted materials possessing antibacterial properties for production of sportswear and thermal underwear. Giving bacteriostatic and antibacterial properties of knitted materials used in conditions of medium and high physical activity and increased sweating of the human body is necessary to minimize the development of pathogenic microflora in the space under the clothes.

To obtain fibrous materials with antibacterial properties, an effective method is the application of an antibacterial preparation in the form of an aqueous colloidal solution of silver nanoparticles under radio-frequency induction low-pressure plasma [1]. The advantages of this method of modification is low energy consumption and environmental friendliness.

2. Materials, methods and equipment
Application radio-frequency induction plasma of low pressure in the processes of modification of knitted material with silver nanoparticles to impart antibacterial properties was investigated on samples of knitted polyester material (JSC «Trikotaj», Yaroslavl), an antibacterial drug selected colloidal aqueous solution of silver nanoparticles Agbion-2 (JSC «Concern «Nanoindustry», Moscow).

The experimental radio-frequency plasma installation of induction discharge of the lowered pressure was applied for modification of textile polyester knitted materials. Application of nanoparticles on knitted materials was carried out with the help of a device that provides obtaining and supplying a mixture of plasma-forming gas and silver nanoparticles from colloidal solution to the discharge chamber [2].
To assess the effectiveness of modification of materials with silver nanoparticles using plasma treatment amount of silver contained in the sample before and after 5 washing cycles simulating washing cycles under normal operating conditions of the product was determined. The amount of silver contained in each sample was determined by atomic emission analysis using ICP spectrometer iCAP 6300 DUO. Uniformity of distribution of antibacterial preparation on the surface of textile fibers was determined by confocal laser scanning microscopy on Olympus OLS Lext 4100. To assess the antibacterial activity of knitted materials, the method of studying the sensitivity of microorganisms to the action of antibiotics and antiseptics on solid nutrient media (diffusion method of paper disks) in modification was used.

3. Results

To establish the regularities of the impact of low-pressure plasma on the samples of textile fabrics processing was carried out at the following input parameters of the installation: voltage at the anode of the generator lamp $U_a = 4$ kV; current at the anode of the generator lamp $I_a = 0.5-1.3$ A; processing time $t = 30-90$ s; flow rate of plasma gas $G = 0.04$ g/s; pressure in the working chamber $P = 50$ Pa; gas of plasma – argon. For application on knitted materials used colloidal solution of silver nanoparticles concentration $C = 0.1$ %.

Evaluation of antibacterial activity of knitted materials before and after their modification by silver nanoparticles in the conditions of low-pressure discharge plasma was carried out by determining the growth delay zone for the *Bacillus subtilis* test culture (fig. 1).

![Control sample: no zone of growth inhibition](image1.png)  ![Modified sample: the zone of growth inhibition $R = 23$ mm](image2.png)

**Figure 1.** Antibacterial activity of knitted material before and after its modification by silver nanoparticles with the use of radio-frequency induction plasma

The test culture *Bacillus subtilis* used in this study is traditionally a model that has a common origin, mechanisms of storage and implementation of hereditary information, as well as the similarity of metabolism with microorganisms present in the human microflora. Studies conducted on a model test cultures allow to assert that the obtained knitted fabrics modified with silver nanoparticles possess antibacterial properties in relation pathogenic microflora.

Uniformity of distribution of the antibacterial preparation put on knitted materials in the conditions of radio-frequency plasma of the lowered pressure was estimated by confocal laser scanning microscopy method (fig. 2). The obtained results show that the application of silver nanoparticles on the surface of knitted materials by this method makes it possible to achieve a fairly uniform distribution of the antibacterial drug on the surface of the materials.
Figure 2. Microphotography of the fiber surface (×10000): the initial sample (a); the sample modified by silver nanoparticles in the conditions of low-pressure discharge plasma (b)

Stability of antibacterial preparation fixing on the surface of knitted materials was evaluated by determining the amount of silver contained in the sample before and after 5 washing cycles. The samples were washed for 20 minutes in tap water with the addition of surfactants at a water temperature of 40°C. The results of stability of silver nanoparticles fixation in the surface layer of knitted materials are shown in fig. 3.

![Graph showing the amount of silver on the sample surface after different cleaning cycles.](image)

**Figure 3.** Stability of fixation of silver nanoparticles on the surface of knitted materials

The results show that the application of silver nanoparticles in the conditions of low-pressure discharge of radio-frequency plasma does not provide enough effective fixation of silver nanoparticles in the surface layer of the material, which leads to the washing out of the antibacterial preparation during the operation of the product and, as a consequence, reduce its antibacterial properties.

4. Conclusions
A number of researches have shown that the method of application of silver nanoparticles in the plasma discharge of low pressure on the surface of knitted materials allows you to evenly apply the antibacterial preparation on the surface of textiles, but does not lead to its effective fixation in the
surface layer of the material. Therefore, this method of modification is relevant for the production of textile materials with antibacterial properties intended for single use.

References

[1] Abdullin I Sh 2011 Izuchenie mehanizma formirovaniya metallicheskih nanopokryitiy na poverhnosti volosyanogo pokrova meha i ih vliyanie na kachestvennyie harakteristiki mehovogo polufabrikata [The study of the mechanism of formation of metal nanocoatings on the surface of fur hair and their impact on the quality characteristics of semi-finished fur] / I Sh Abdullin, E A Pankov, V A Usenko // Izvestiya vyisshih uchebnyih zavedenii. Tekhnologiya legkoy promyishlennosti. – №2, P. 77-80 (In Russian).

[2] Pankova Y A 2011 Mehanizmy naneseniya nanochastits serebra i ih fiksatsii v struture mehovogo polufabrikata [Mechanisms of application of nanoparticles of silver and their fixation in the structure of semi-finished fur] / E A Pankova / VI international scientific and practical conference of students and young scientists «New technologies and materials of light industry». – Kazan, P. 34-37 (In Russian).