Study of the effect of plasma modification on the change of fire-resistant properties of textile materials imported by flame retardants

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Abstract. The article studies the effect of plasma modification on the flame retardant properties of blended fabrics. The regime of plasma treatment is revealed at which effective and uniform solution absorption of the flame retardant composition of textile materials is achieved. It was found that the most effective fixing of the flame retardant is carried out on samples that underwent double plasma treatment before and after impregnation with the flame retardant.

1. Introduction

One of the main directions of solving the task of creating safe working conditions is the development and provision of workers with effective personal protective equipment, reliably protecting people from exposure to harmful factors in the aftermath of accidents associated with exposure to chemically hazardous substances and accompanied fires.

One of the main methods for producing fire-resistant material is impregnation textile material of a flame retardant. Processing textile materials by flame retardants reduces the fire risk of fibers, yarns, fabrics, nonwovens and products from them, including protective clothing. As a result of processing by effective means of fire protection, the possibility of ignition of textile materials from low-calorie sources of ignition (cigarette, match, etc.) is excluded. In other cases these means limit the spread of the flame over the surface, reduce the smoke-generating ability, the toxicity of thermal decomposition products and heat release.
To the materials used for the manufacture of fire-resistant personal protective equipment, presented a set of different requirements. So, in addition to high fire resistance, they must have air and vapor permeability, low rigidity, wear resistance and resistance to pollution.

To impart flame retardant properties of cellulose materials and fabrics from a mixture of cellulose and synthetic fibers, the following methods are used:

1) Impregnation of fabrics with solutions of flame retardants (surface treatment);
2) The chemical modification of fibers and products from them;
3) The introduction of flame retardants in the melt or the molding polymer solution.

The choice of this or that method in each particular case is determined by the required degree of fire protection and by how firmly the flame retardant properties are maintained after multiple water treatments (washes), also by the level of physical and mechanical properties of the fibers and fabrics.

Among the most investment-attractive methods for imparting flame retardant properties is the treatment of textile materials with flame retardants at the finishing stage, including the use of high-frequency capacitive (HFC) discharge plasma [1].

Processing of textile materials with HFC discharge plasma does not increase the fire resistance of materials in the absence of fireproof finishing agents. However, plasma processing allows you to adjust the surface properties of materials in a wide range, and depending on the parameters can improve the hydrophilic properties of textile material, increase the wettability of the fabric, which will lead to a more efficient and uniform solution absorption [2].

The aim of the work is to study the effect of plasma treatment on the fire-resistant properties of textile materials.

2. Materials and methods
The objective of the study selected blended fabrics: article number S-99/2 UG (80% cotton, 20% polyester) and article number S-182-UG (53% cotton, 47% polyester). An intumescent fire retardant obtained at the Department of Technology of Chemical, Natural Fibers and Products according to the technology of joint stock company KazHimNII was chosen.

The plasma treatment was carried out on an experimental high-frequency plasma plant of reduced pressure, described in [4], using as an argon plasma-forming gas, and a mixture of argon / propane-butane gases in a ratio of 70/30.

3. Results of experiments and discussion
The processing of the fabrics thread in a high-frequency plasma installation was carried out with the power variation. At the first stage of the studies, processing of the samples of the fabrics was performed in an industrial plasma installation with plasma-forming gas argon. The value of plasma gas flow (G) was 0.04 g/s, a generator frequency (f) was 13.56 MHz, and pressure (P) in the vacuum chamber was 26.6 Pa, a processing time (t) 3 min. The discharge power (Wp) varied from 0.1 to 0.9 kW.

It is known [3, 4] that when exposed to the textile materials of the HFC-discharge plasma, there is a directional change in the surface properties of the material being processed. Therefore a plasma treatment regime was searched for, at which the optimum value of the weight gain of textile materials after impregnation with a flame retardant is observed. Table 1 shows the results of changes in the weight gain of control and plasma-modified samples of textile materials.
Table 1. Values of weight gain of samples at the selected plasma processing parameters.

| Power (Wp), kW | Weight gain, % | S-99/2 UG | S-182-UG |
|---------------|---------------|-----------|-----------|
| Control sample | 19.0          | 17.5      |           |
| 0.2           | 25.4          | 22.5      |           |
| 0.3           | 27.8          | 25.9      |           |
| 0.4           | 31.3          | 30.8      |           |
| 0.5           | 31.7          | 31.5      |           |
| 0.6           | 36.8          | 35.3      |           |
| 0.7           | 44.1          | 42.8      |           |
| 0.8           | 32.8          | 32.2      |           |
| 0.9           | 27.2          | 27.0      |           |

It was established that after processing samples of textile materials in the mode: Wp = 0.7 kW, t = 3min, P = 26.6Pa, G = 0.04g/s, argon gas, the values of the weight gain of the samples increase 2.32 times for fabric S-99/2 UG and 2.45 times for fabric S-182-UG.

The study of changes in the flame retardant properties of textile materials after impregnation with a flame retardant and plasma modification was determined after exposure to an open flame.

On the basis of experimental data, it was found that tissue samples treated with HFU-discharge plasma followed by impregnation with intumescent fire retardant, have fire-resistant properties. Plasma treatment promotes effective and uniform dissolution of the surface of textile materials.

During the operation and repeated washings of flame retardant textile materials obtained by impregnation by fire retardants, the flame retardant impregnation from the surface of the material is washed out and the material loses its flame retardant properties. Textile samples underwent washing steps, after which they were tested for resistance to open flame. It was revealed that after five cycles the flame retardant washes out, textile materials lose their flame retardant properties and are exposed to an open flame.

In this regard, the actual problem remains fixing the flame retardant in the surface layer of textile material. Therefore, at the next stage of work, research was carried out on the effectiveness of plasma treatment to fix intumescent flame retardant on the surface of textile materials.

An analysis of previous studies [2-5] showed that repeated plasma treatment contributes to additional fixing the impregnating composition into the surface of the material due to ion bombardment, which leads to physical adsorption of the impregnation in the surface layer, as well as the formation of a surface mesh due to the presence of molecules propane-butane. In this regard, samples of textile materials that underwent plasma treatment and subsequent impregnation with a flame retardant were subjected to repeated treatment in the medium of an argon-propane / butane gas mixture in a ratio of 70/30.

At the second stage of the studies, the textile samples were processed in an experimental plasma installation with a plasma-forming gas flow argon / propane-butane in the ratio of 70/30. The value of plasma gas flow (G) was 0.04 g/s, a generator frequency (f) was 13.56 MHz, and pressure (P) in the vacuum chamber was 26.6 Pa, a processing time (t) 3 min, discharge power (Wp) 0.7 kW. Figure 1 shows the change in weight gain of tissue samples after five wash cycles.
Figure 1. Change in weight gain of tissue samples after five wash cycles.

It has been established that samples of textile materials that have undergone repeated plasma treatment after five washing cycles lose 58% and 67% of weight gain, a partial washing out of the flame retardant occurs. However, even after five wash cycles, textile samples retained flame-retardant properties.

4. Conclusions
It was revealed that the intumescent fire retardant was most effective and fixed on the samples that underwent double plasma treatment before and after impregnation with the flame retardant.

References
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