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A nature-like anti-infective impregnation of a medical mask and a method for its application

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Abstract: **The potential for creating anti-infective impregnation based on aminopolysaccharide and silver ions is shown. Thanks to a unique water-insoluble complex of silver clusters (Ag 0.034 mg/cm^2 of mask material) in natural aminopolysaccharide, the impregnated material exhibits significant antibacterial properties. It has been shown that impregnation does not interfere with the effective removal of carbon dioxide, which can accumulate on the inside of the mask during breathing. It is noted that the use of a new nature-like anti-infective impregnation opens up the possibility of increasing the wear resistance of the impregnated material, while the impregnation is not removed from the surface of the mask material during intensive use of the mask.**

Keywords: **medical masks, impregnation, aminopolysaccharides, silver, antibacterial effect**

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Contents

1. INTRODUCTION

Due to the numerous mutations of the new coronavirus infection COVID-19, the SARS-CoV-2 virus contains a lot of unpredictable complications. Despite the fact that the pandemic is over, today preventive measures for the non-proliferation of viral infections remain relevant [1-3]. The most common preventive measure is the wearing of a medical mask [4]. The medical mask is designed for an infected person and detains aerosols with viruses that he forms when talking, coughing and sneezing. The disadvantages of using medical masks include the following factors:

- loose fit to the nose and mouth, the presence of gaps;
- touching the mask promotes the transfer of viruses to the skin of the face and hands, which increases the chances of their penetration into the body;
- wetting the mask significantly reduces its protective qualities;
- wearing a mask for more than the specified time, repeated use of disposable masks;
- significant accumulation of viruses on the mask promotes their penetration through the protective barrier.

Continuous wearing of one mask for more than 4 hours leads to oxygen deficiency and thus leads to headache, nausea, fatigue and loss of concentration. The gas permeability of the mask decreases over time and there is an accumulation of CO_2 in the undermask space, hence in the body, which negatively affects the immune system, as well as the condition of the skin of the face, nasal mucosa and mouth.

Thus, when using medical masks, the following problems remain unresolved:

- Penetration of infectious agents through the pores of the mask during intensive breathing, including when using the mask by an infected person;
- Accumulation of infectious agents on the inside of the mask during breathing;
- Accumulation of carbon dioxide on the inside of the mask when breathing.

This work is devoted to the research of a new nature-like anti-infective mask impregnation, which is aimed at solving the existing problems of medical masks.

2. MATERIALS AND METHODS

The objects of research were disposable medical masks made of non-woven spunbond material. The spunbond was impregnated sequentially with two solutions by four procedures:

1. Application of an impregnating solution, a natural aminopolysaccharide with the inclusion of colloidal silver ions by the method of uniform micro-droplet spraying at the rate of 0.01 ml of solution per 1 cm^2 of spunbond.
2. Drying of spunbond in a hot air stream (80-120°C).
3. Application of the fixative (know-how), by the method of uniform micro-droplet spraying, after which the aminopolysaccharide takes it forms a water-insoluble form and forms clusters of silver that will not be removed from the spunbond when breathing.
4. Spunbond drying: wet spunbond is dried in a stream of hot air (80-120°C).

During drying, the aminopolysaccharide with silver ions is fixed at the pores, while the remnants of the fixative evaporate from the surface of the spunbond.

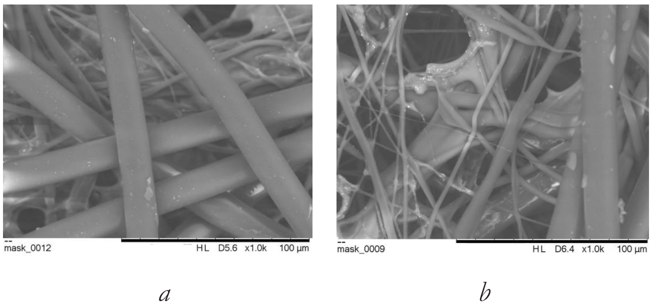
Then comparative physicochemical and microbiological studies were carried out with the masks. Atomic emission spectrometry with inductively coupled plasma of extracts from the mask material was carried out on the iCAP 6300 Duo device (Thermo Fisher Scientific, USA) by the method described in [5]. Energy dispersive *X*-ray spectroscopy based on a scanning electron microscope of mask material was performed on a Hitachi TM3030 scanning electron microscope (Hitachi Ltd., Japan) with an energy dispersive *X*-ray spectroscopy (EDS) Quantax system 70 (Bruker Nano GmbH, Germany) [6]. *X*-ray fluorescence analysis of the mask material was carried out using an Amptek semiconductor SDD Peltier cooled *X*-ray detector. The results were obtained under the following operating modes of the *X*-ray tube: 35 kV high voltage, the current is 20 mkA, the anode-Cr is a through-type. The irradiation area is 3 mm. The angle of incidence of *X*–ray radiation on the sample is 450, the sampling angle is 450. Physico-chemical quantitative determination CO_2 in the gas samples of the undermask space were carried out by the method described in [7].

Further, comparative tests of impregnated and non-impregnated masks for contamination with aerobic microorganisms when worn on the face and intensive breathing of a person for 1 hour were carried out. After use, the masks were placed in a hermetically sealed sterile plastic container and sent for microbiological analysis.

Microbiological determination of the total number of aerobic microorganisms on the mask tissue was determined by the method described in [8].

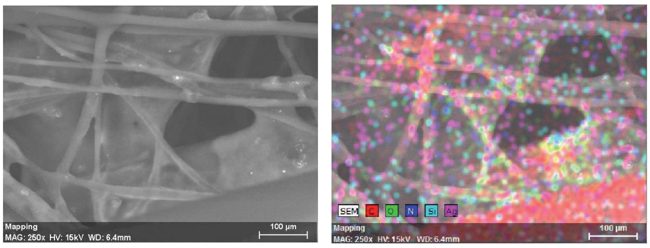
3. RESULTS AND DISCUSSIONS

A comparative analysis of microphotographs of impregnated and non-impregnated masks obtained using a scanning electron microscopy showed that the fibers of the studied material of the impregnated medical mask are everywhere covered with a gel-like colorless substance that does not violate the structure of the material and the size of the pores (**Fig. 1**).



a *b*

Fig. 1. *Microphotographs of mask material obtained using a scanning electron microscope: a – non-impregnated mask, b - impregnated mask.*



a *b*

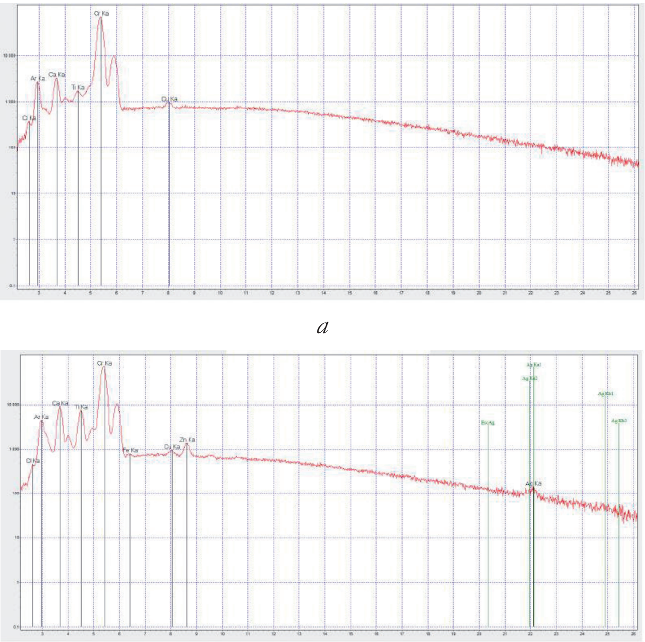
Fig. 2. *Microphotography of the impregnated mask material obtained by energy dispersive X-ray spectroscopy (b) on the basis of a scanning electron microscope (a).*

Analysis of the material of the impregnated mask using energy dispersive *X*-ray spectroscopy based on a scanning electron microscopy showed the presence of silver and silicon ions (**Fig. 2**).

The data of energy dispersive X-ray spectroscopy based on a scanning electron microscopy were confirmed by *X*-ray fluorescence analysis (**Fig. 3**).

In addition to silver, zinc and traces of iron were found in the impregnated mask, in contrast to the non-impregnated mask. It is also noted that the impregnated mask has an increased titanium content compared to non-impregnated mask.

The analysis by atomic emission spectrometry with inductively coupled plasma of extracts from mask material showed the silver content on the impregnated mask in contrast to the non-impregnated mask (**Table 1**).



a

b

Fig. 3. *Spectra of X–ray fluorescence analysis of mask material: a – non-impregnated mask, b - impregnated mask.*

Table 1

Comparative content of silver, accumulation of carbon dioxide in exhaled air in non-impregnated and impregnated masks and the content of microorganisms on the mask material after 1 hour of use

The mask name	Ag mg/cm^2 of mask material	Carbon dioxide content, %	Total aerobic bacterial count, CFU/g mask
Non-impregnated mask	0.000	0.5	190
Impregnated mask	0.034±0.001	0.5	10

Studies on a stand with a breathing machine for determining the content of carbon dioxide in the undermask space were conducted up to the maximum value of carbon dioxide in the undermask space, with a well-established breathing cycle, until a stable value of the carbon dioxide content in the exhaled air was established. The retention of carbon dioxide in the undermask space depends on the permeability and density of the filter material. The permeability of the tested masks was 72-76%. With such permeability, fluctuations in carbon dioxide retention are insignificant.

As a result of the data obtained, it was concluded that there was no deterioration in the gas permeability of the impregnated mask compared to the non-impregnated one. At the same time, the removal of carbon dioxide from the undermask space remained at the same level, despite the impregnation and filling of the pores of the mask with natural anti-infective aminopolysaccharide (Table 1).

4. CONCLUSION

At the end of the research cycle, comparative tests of non-impregnated and impregnated masks for bacteriological contamination of the mask material adjacent to the face after 1 hour of use were carried out. The antibacterial effect of the impregnated mask was significantly increased (19 times) compared to the non-impregnated mask (Table 1).

These results show the potential to create a new anti-infective impregnation:

- due to the unique complex of silver clusters in the natural aminopolysaccharide, the impregnated material exhibits significant antibacterial properties;
- the impregnation does not prevent the effective removal of carbon dioxide, which can accumulate on the inside of the mask when breathing.

The use of a new nature-like anti-infective impregnation opens up the possibility of increasing the wear resistance of the impregnated material, while the water-insoluble impregnation is not removed with intensive use of the treated mask. In the future, it is planned to test the impregnated mask for resistance to washing in water, resistance to pathogenic microorganisms and viruses, as well as the absence of the release of harmful substances and allergens to human skin when used.

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