Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2025, т. 23, № 1, сс. 229–239
https://doi.org/10.15407/nnn.23.01.0229

PACS numbers: 47.85.M-, 81.05.Lg, 81.20.Hy, 83.50.Uv, 83.80.Mc, 83.80.Wx, 87.85.Rs

Research into Nanomodified Textile Materials with Multifunctional Properties

N. M. Bereznenko[1], S. M. Bereznenko[2], H. I. Kupalova[1],
N. V. Honcharenko[1], and H. A. Ripka[2]

[1]*Taras Shevchenko National University of Kyiv,*
64/13, Volodymyrska Str.,
UA-01601 Kyiv, Ukraine
[2]*Volodymyr Dahl East Ukrainian National University,*
17, Ioanna Pavla II Str.,
UA-01042 Kyiv, Ukraine

The article discusses the use of nanotechnology in the production of textile materials. Considering the fact that a person today is affected by many external factors, which can cause a negative impact on his body, the creation of tissue packages with multifunctional properties is appropriate. The work presents the results of research into the properties of textile materials using nanofibres; the impact of created materials on the human body is investigated; methods of packaging clothing details are studied; methods and means of creating packages of textile materials using nanomodified materials are investigated. Particular attention is paid to the issue of methods of connecting packages of textile materials using nanomodified components, in particular, attention is focused on the option of creating a package of materials with the addition of nanomodified components, which consists of two non-woven materials different in their raw material composition (70% hemp fibres and 30% polyester including 15% low-melting polyethylene) and non-woven material obtained by the adhesive method with antimicrobial properties, which are connected by an adhesive thread. The creation of such a package solves the problem of providing the necessary elastic properties, and an additional layer of nanomaterial based on nanomodified fibres ensures the antibacterial properties of the package. The work proposes to use textile materials with certain properties in those parts of clothing, where it is necessary.

У статті розглянуто питання використання нанотехнологій у виробництві текстильних матеріялів. Враховуючи те, що на людину сьогодні діє багато зовнішніх чинників, які можуть спричинити неґативний вплив на її організм, створення пакетів тканин з поліфункціональними властивостями є доречним. В роботі представлено результати досліджень властивостей текстильних матеріялів з використанням нановолокон, вивчено вплив створених матеріялів на організм людини, вивчено методи пакетування деталів одягу, досліджено методи та засоби створення пакетів текстильних матеріялів з використанням наномодифікованих матеріялів. Окрему увагу приділено питанню методів з'єднання пакетів текстильних матеріялів з використанням наномодифікованих компонентів, зокрема зосереджено увагу на варіянті створення пакету матеріялів з додаванням наномодифікованих компонентів, який складається з двох нетканих матеріялів, різних за своїм сировинним складом (70% конопляних волокон і 30% поліефіру, в т.ч. 15% низькотопкого поліетилену) та нетканого матеріялу, одержаного клейовим методом, з антимікробними властивостями, які з'єднані клейовою ниткою. Створення такого пакету вирішує проблему забезпечення необхідних пружніх властивостей, а додатковий прошарок наноматеріялу на основі наномодифікованих волокон забезпечує антибактеріяльні властивості пакету. В роботі пропонується застосовувати текстильні матеріяли з визначеними властивостями в тих частинах одягу, де це необхідно.

Key words: nanomaterials, dimensional stability, fibres, polyethylene.

Ключові слова: наноматеріяли, стабільність розмірів, волокна, поліетилен.

(Received 8 January, 2024; in revised form, 2 September, 2024)

1. INTRODUCTION

The new millennium has witnessed significant research and development worldwide in the field of nanotextile development. In recent years, a number of innovative approaches have been implemented, which tend to apply the functional properties and adaptation of fabrics to specific requirements. The main and most promising direction of expanding the assortment and improving the properties of textile materials of various compositions is not the development of new types of chemicals for the production of textile fibres, but the modification of already existing fibres and finished textile materials in order to give them new properties.

The results of the research of nanomaterials have created a great potential for the production, and the synthesis of high-tech materials of a new generation with improved properties, or with completely new, previously unknown, valuable properties. When developing this method, the main problem is to identify the regularity of the combination of different molecular structures to create nanomaterials with predetermined properties.

The study of these issues makes it possible to expand the information space, scientific and industrial cooperation with other countries, and expand the sales market for products of the national manufacturer, including scientific ones. The possibility of Ukraine's participation in these processes as an equal partner exists only under the condition of carrying out developments or producing competitive products. Today, without the latest achievements, it is impossible to solve the task of providing textile materials in various spheres of the economy: automobile construction, road construction, the agricultural sector, the development of health care items, personal protection, *etc*. Based on this, it is possible to establish the fact that the problem of finding ways to create high-quality nanomodified materials for various fields of application is a priority direction for the development of the global textile industry and should become such for Ukraine.

2. EXPERIMENTAL DETAILS

The term 'nanotechnology' was first used and put into circulation in 1974 by the Japanese scientist Professor Norio Taniguchi of the University of Tokyo, but only in 1980 the measuring and working equipment necessary to work with nanoscale objects appear appeared [1]. Later, more and more companies began to invest in the development of nanotechnology. Today, many countries of the world are conducting intensive fundamental research on the creation of new nanomaterials with special properties [2–4].

Thus, it can be stated that the development of nanotechnology is taking over the world on a large scale, while not separating the use of nanoparticles in certain branches of production, which makes it possible to optimize the process of manufacturing various textile materials, and as a result, clothes, which can be used for various purposes, starting from clothes for everyday use and ending with workwear.

At the moment, the use of materials with multifunctional properties is gaining more and more importance, because with the development of science, technology and human needs, the properties that materials should have are constantly changing. Therefore, the use of fabrics with nanoparticles, and, as a result, textile materials with multifunctional properties, is of great importance to humankind and is actively being implemented in production.

The analysis of global trends in the development of textiles indicates a fundamental change in the concept of 'multifunctional textiles'. The main task that is solved when creating nanotextiles is to ensure the necessary set of properties depending on the type of product. In this regard, in the last five to seven years, a new approach has been formed in the development of textile materials for a new purpose—the creation of multifunctional materials. When designing multifunctional nanotextiles, one has to solve the problem of combining several necessary properties, sometimes opposite ones, in one material. The possibility of solving this problem depends on a rational combination of the properties of the raw materials, the structure of textile materials and the technology of their production. One of the ways to solve such compromise problems can be the creation of multilayer textile composite products by connecting (layering) individual textile products with different properties into one structure. This method makes it possible to use the advantages of each of the components and provides a fundamental opportunity to vary the properties of materials within the fairly wide limits. Polyfunctional textile composite materials can find qualified applications in various industries.

A promising direction is the study and improvement of technologies for obtaining non-woven materials, fabrics and products made of fibres, threads or other types of materials (textile and their combinations with non-textile, for example, films) without the use of spinning and weaving [6, 7]. In comparison with the traditional methods of production in the textile industry, namely, weaving and spinning, the production of non-woven materials is distinguished by the simplicity of the technology (including the reduction of the number of technological stages), the increase in the productivity of the equipment and, therefore, lower capital and labour costs, the variety of the range of cloths, the possibilities rational use of various raw materials, lower cost of production, implementation of maximum automation of production, *i.e.*, creation of flow lines and automatic factories, and non-woven materials themselves have high operational properties. Therefore, non-woven materials have become one of the main types of modern textile products, although their large-scale industrial production appeared only in the 1940s of the 20th century. At the moment, the production of non-woven materials is quite important, because their properties allow them to be used quite widely in various areas, for example, household, medicine, construction [8].

Packaging of clothing parts is carried out in various ways: thread, glue, welded [9]. The use of one or another connection in each specific case depends on the requirements for it, the type of connection of materials, the thickness of the package, as well as on the power and capabilities of the equipment used. Thus, work [10] shows the effective use of polymer sheets in the interlayer between fabrics, which become thinner as humidity increases, thereby reducing the gap between fabrics and reducing thermal insulation. Such moisture-sensitive polymers can be effectively used for the manufacture of clothing, which will provide comfortable conditions for being in it. Regarding the production and use of non-woven materials in the manufacture of clothes, the important point of using this or that connection in each specific case depends on the requirements for it, the type of connection of materials, the thickness of the package, as well as on the power and capabilities the equipment used.

The connection of layers of materials with the help of an adhesive thread that has antimicrobial properties can be considered as one of their alternative methods of packaging materials. Adhesive thread is a monofilament or polyfilament fibre made of a thermoplastic polymer. Adhesive thread is used to connect inconspicuously parts of clothing or a package. The second direction of using such a thread is the creation of non-woven materials from synthetic and natural fibres and their use in the creation of bags. The quality of the created package depends on the characteristics of the main material, the spacer material and the duplicating modes. Taking into account the above, there was a need to determine the technical and technological capabilities of nanomodified materials, including nonwovens, and packages based on them.

The HB-1 installation was used to produce non-woven materials from thermoplastic polymers. This equipment can produce tubular frameless filter elements, roll materials from heat-bonded fibres, *etc.*, as well as non-woven materials, the structure of which in our case includes components in combination with nanomodified polyethylene fibres and polyethylene fibres of the 2212 brand (15%), which provide gluing of non-woven fabrics. Non-woven material is made by physicochemical method of binding fibrous base. Fibres (threads) in the fabric are fastened into a single system due to adhesive interaction at the interface between the binder and fibre (thread). Elastomers, thermoplastic and thermoset polymers in the form of dispersions, solutions, aerosols, powders, fusible and bicomponent fibres are usually used as binders. Sometimes binders are not used; in this case, the basis of non-woven materials is subjected to a special treatment (heat, chemical reagents, gases), which leads to a decrease in the flow of the polymer from which the fibres (threads) of the fibrous basis are made, or to the appearance of 'stickiness' on their surface as a result of swelling, plasticization, which contributes to the bonding of fibres in the places of their contact.

In the presented work, the starting materials for determining the rational parameters of duplication when creating packages with nanomodified elements are adhesive threads, the composition of which is polyethylene 2212 + 1% Sevilen + 0.5% antimicrobial additive and polyethylene 2212, a non-woven material obtained by the adhesive method with the addition of silver nanoparticles, namely, non-woven material, in which 70% are natural fibres (hemp), 30% are synthetic (polypropylene, polyester, including 15% low-melting components (polyethylene, polyester)), and top material (suit fabric 68632).

During planar duplication, it is necessary to ensure uniform pressure, material heating temperature and constant temperature control directly in the package-gluing zone. These requirements are met by the semi-automatic VTO-1 installation modernized taking into account modern technical capabilities. The unit includes upper and lower pads with an adjustable heating temperature of 100–2000°C. If necessary, the design of the pads allows you to simulate wet heat treatment processes using steam and vacuum suction.

3. RESULTS AND DISCUSSION

Previous studies [11] demonstrated the possibility of using polyethylene threads of the 2012 series nanomodified with silver particles. Research results show that the use of nanomaterials, in particular silver-based, is an effective alternative to traditional methods of combating microorganisms and microbes. This is explained by the multiple resistances of the latter to drugs (for example, antibiotics). Instead, nanomaterials with silver particles make it possible to achieve impressive antimicrobial efficiency thanks to their increased surface area, shape and size [12, 13]. In the presented work, the duplication of costume fabric 68632 with a non-woven nanomodified material using the above-mentioned polyethylene threads was investigated and carried out on the VTO-1 installation with the parameters indicated in Table 1. As elements of the package, the costume fabric 68632 (wool—40%, viscose—40%, polyethylene—

TABLE 1. Comparative assessment of the quality of duplicating costume fabric 68632 with non-woven nanomodified material (NM) using polyethylene threads of the 2212 series.

No. of package	Temperature of the upper and lower pads of the press, T, °C	Duplication time, t, s	Pressure, Pa	Duplication quality assessment
1	140 100	20	33.75	The adhesive thread melted a little, but the gluing process did not take place
2	150 100	20	33.75	NM stuck to the fabric without infraction the structure of the top
3	160 100	20	33.75	Partial melting of NM occurs

20%), non-woven material modified with silver nanoparticles, polyethylene thread (article: 2012) are involved.

The given data indicate the expediency of using the second version of the duplication parameters, but it was found that, in other versions, there is a waviness of the fabric of the top (Fig. 1).

Further studies of duplication processes are associated with change in some parameters, namely, time and temperature. The results are shown in Table 2.

The given data indicate the need to adjust the duplication time. At the same time, the best duplicating results are provided when using polyethylene threads, which are thermally stabilized at $T = 110°C$. Such threads provide sufficient strength of the adhesive connection.

Thus, the following duplicating parameters can be considered rational: $T_{v.p} = 150°C$, $t = 15$ s.

One of the options for packaging materials with the addition of

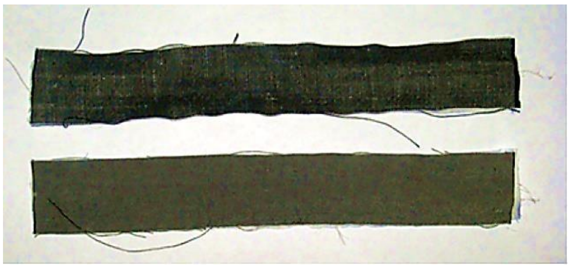

Fig. 1. General appearance of the fabric of the top after duplicating it with non-woven material.

TABLE 2. Comparative assessment of the quality of duplicating costume fabric 68632 with non-woven nanomodified material using polyethylene threads.

No. of package	Temperature of thermostabilization of polyethylene threads, T, °C	Duplication time, t, s	Duplication quality assessment
1	without thermostabilization	20	waviness
1*		15	satisfies
2	110	20	satisfies
2*	110	15	satisfies
3	120	20	waviness
3*	120	15	smaller waviness
4	130	20	waviness
4*	130	15	smaller waviness

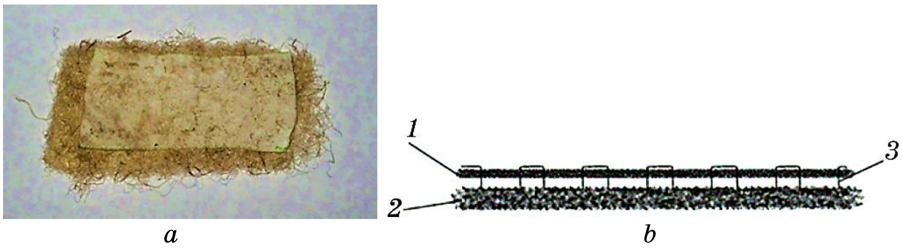

Fig. 2. Package containing nanomodified components: *a*) appearance; *b*) section, where *1*—non-woven material (100% polypropylene); *2*—non-woven material based on hemp fibres (70% hemp fibres, 30% low-melting substances); *3*—polyethylene threads.

TABLE 3. Determination of the growth retardation zone of *Saures* ATCC 25923 and *C. aibicaus* HT 885-653 of nanomodified non-woven materials based on polypropylene (PP) A7.

No. example	PP without bactericidal components	*Saures*, growth retardation zone	*C. aibicaus*, growth retardation zone
1	PP without a bactericidal component	0	0
2	PP modified with 0.5% Ag	3–4	0–1
3	PP modified with 0.5% Cu	4–5	1–3
4	PP is impregnated with a nanocomponent of Ag	12–17	5–8
5	After washing	4–6	4–6

nanomodified components is a package consisting of two non-woven materials that differ in their raw material composition. Figure 2 shows a package consisting of non-woven material (70% hemp fibres and 30% polyester, including 15% low-melting polyethylene) and non-woven material obtained by the adhesive method with antimicrobial properties (Table 3), connected by an adhesive thread of the 2012 series. The creation of such package solves the problem of providing the necessary elastic properties, and an additional layer of nanomaterial based on nanomodified fibres ensures the antibacterial properties of the package.

As can be seen from the above data, even a small introduction of Ag and Cu nanoparticles (0.0002–0.0004% by mass) into the PP structure has an antimicrobial and biostatic effect [8].

It is advisable to use such package in those areas of clothing

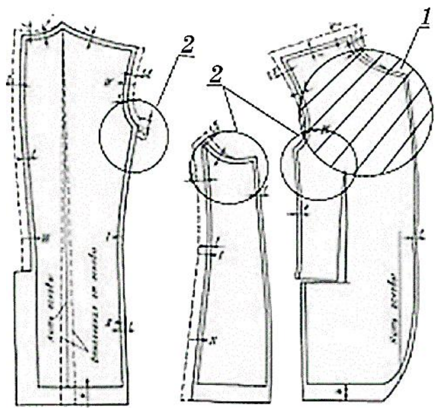

Fig. 3. Areas of use of the package in clothing: *1*—locations of the designed package to ensure dimensional stability; *2*—locations of the developed package to ensure human protection against the pathogenic effects of microflora (viruses, fungi, microbes).

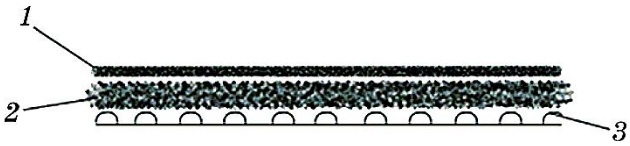

Fig. 4. An example of using a pad made of nanomodified materials (section of a package): *1*—non-woven material (100% polypropylene); *2*—non-woven material based on hemp fibres (70% hemp fibres, 30% low-melting substances); *3*—polyethylene threads; *4*—adhesive material.

where it is necessary to ensure dimensional stability (Fig. 3, position *1*) and to protect a person from the pathogenic influence of microflora (viruses, fungi, microbes) (Fig. 3, position *2*).

As a substrate in such a package, it is advisable to use an adhesive material that is in contact with a non-woven material based on hemp fibres (Figs. 3 and 4). This technology will make it possible to use this package as an additional part of clothing, for example, an insulating lining for hats or outerwear. According to the raw material composition, the first layer of the bag is made of non-woven material (polypropylene), which allows moisture to pass inside the bag, where the second layer is placed, namely, a non-woven canvas based on hemp fibres, which has good sorption and antimicrobial properties, which will allow the bag to perform a barrier function.

According to Refs. [14, 15], hemp fibres neutralize the microbial environment, and the barrier function is manifested in a positive effect on the functional state of organs and organ systems, in addi-

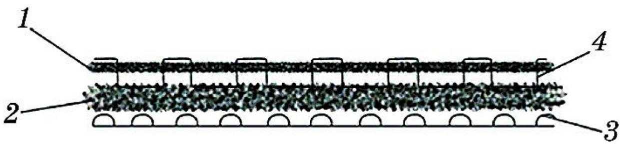

Fig. 5. Package with the content of nanomodified components in cross-section: *1*—non-woven material (100% polypropylene); *2*—non-woven material based on hemp fibres (70% hemp fibres, 15% polyethylene, 15% low-melting substances); *3*—adhesive material, which can serve as a substrate.

tion, hemp cotinine fibres exceed cotton fibres by 95% in breaking load.

The studies given in the Table 2 make it possible to create such packages without using adhesive thread (Fig. 5).

The melting point of non-woven polypropylene material is 150–154°C, which makes it possible to make an adhesive connection with another non-woven fabric by melting a certain part of the non-woven polypropylene material itself.

4. CONCLUSION

The presented studies of materials with multifunctional properties allow solving a number of issues in the creation of light industry products for various purposes, namely: inhibition of the vital activity of microflora (antimicrobial activity is two times higher than the antimicrobial properties of cotton fabrics); implementation of thermoregulation; ensuring a high rate of dimensional stability.

REFERENCES

1. Henadii Oleksandrovych Androshchuk, Anatolii Vladyslavovych Yamchuk, Nataliia Volodymyrivna Berezniak, Tetiana Kostiantynivna Kvasha et al., *Nanotekhnolohii u XXI Stolitti: Stratehichni Priorytety ta Rynkovi Pidkhody do Vprovadzhennya* [Nanotechnology in the 21st Century: Strategic Priorities and Market Approaches to Implementation] (Kyiv: UkrNTEI: 2011), 272 p. (in Ukrainian).
2. Deepshikha Gupta, Anuj Boora, Amisha Thakur, and Tejendra K. Gupta, *Environmental Research*, **231**, Pt. 3: Article ID 116316 (2023); https://doi.org/10.1016/j.envres.2023.116316
3. Meiwen Cao, *Nanomaterials (Basel)*, **13**, No. 3: 609 (2023); https://doi.org/10.3390/nano13030609
4. Mahesh Uttamrao Shinde, Mohsina Patwekar, Faheem Patwekar, Majed A. Bajaber, Anuradha Medikeri, Firdous Sayeed Mohammad, Mohammad Mukim, Sanjay Soni, Jewel Mallick, and Talha Jawaid, *Journal of Nano-*

materials, **2022**: Article ID 596813 (2022); https://doi.org/10.1155/2022/5968131
5. Basmah H. Alshammari, Maha M. A. Lashin, Muhammad Adil Mahmood, Fahad S. Al-Mubaddel, Nasir Ilyas, Nasir Rahman, Mohammad Sohail, Aurangzeb Khan, Sherzod Shukhratovich Abdullaev, and Rajwali Khan, *RSC Advances*, **13**: 13735 (2023); https://doi.org/10.1039/D3RA01421E
6. Maria Pawłowa and Halina Szafrańska, *Fibres and Textiles in Eastern Europe*, **15**, No. 3 (62): 97 (2007).
7. Limin Bao, Shunsuke Sato, Hideaki Morioka, and Shinya Soma, *Journal of Textile Engineering*, **62**, Iss. 3: 37 (2016); https://doi.org/10.4188/jte.62.37
8. Karthik Thangavel, C. Praba Karan, R. Rathinamoorthy, *Process, Structure, Properties and Applications* (India: Woodhead Publishing Pvt. Ltd.: 2016), 358 p.
9. Tim Cooper and Stella Claxton, *Journal of Cleaner Production*, **351**: Article ID 131394 (2022); https://doi.org/10.1016/j.jclepro.2022.131394
10. Ying Zhong, Fenghua Zhang, Meng Wang, Calvin J. Gardner, Gunwoo Kim, Yanju Liu, Jinsong Leng, Sungho Jin, and Renkun Chen, *Scientific Reports*, **7**: Article ID 44208 (2017); https://doi.org/10.1038/srep44208
11. Sergey Bereznenko, Natalia Bereznenko, Mykola Skyba, Dmytro Yakymchuk, Tetiana Artemenko, Dmytro Prybeha, Oleg Synyuk, and Eugen Kalinsky, *International Jornal of Clothing Science and Technology*, **33**, No. 1: 25 (2021); https://doi.org/10.1108/IJCST-07-2019-0107
12. Shameran Jamal Salih, Sewgil Anwer, and Awara Smail, *Journal of Engineering Sciences*, **6**, Iss. 2: C.1 (2019); https://doi.org/10.21272/jes.2019.6(2).c1
13. Muthupandian Saravanan, Sisir Kumar Barik, Davoodbasha Mubarak Ali, Periyakaruppan Prakash, and Arivalagan Pugazhendhi, *Microbial Pathogenesis*, **116**: 221 (2018); https://doi.org/10.1016/j.micpath.2018.01.038
14. Vishnu Dorugade, Mengistu Taye, Sajid Ahmed Qureshi, Tewodros Agazie, Bihonegn Seyoum, Badasa Abebe, and Srikant Komarabathina, *Journal of Natural Fibers*, **20**, No. 2: Article ID 2211290 (2023); https://doi.org/10.1080/15440478.2023.2211290
15. Malgorzata Zimniewska, *Materials (Basel)*, **15**, No. 5: 1901 (2022); https://doi.org/10.3390/ma15051901