„FILTER MATERIALS BASED ON PLA NONWOVENS MODIFIELD WHIT ZINC OXIDE"

Dominik Borkowski[1], Izabella Krucińska[1], Zbigniew Draczyński[1]
[1] *Department of Material and Commodity Sciences and Textile Metrology, Żeromskiego 116, 90-924 Lodz*
E-mail: dominik.borkowski@edu.p.lodz.pl

ABSTRACT: The following abstract discusses the current knowledge of the modification of polylactic nonwovens with zinc oxide to obtain filter materials. Below is a comparative analysis of PLA nonwovens without nanoaddition with nonwovens containing from 0.5% to 2.5% ZnO in their structure and with varying degrees of quilting.

Key Words: PLA, UPF, zinc oxide

1. INTRODUCTION

From year to year, you can observe an increasingly larger increase in the amount of pollution. The most exposed to pollution are surface waters, which are the main source of drinking water. The continuous population growth and the development of large cities affect the increasing amount of waste including harmful chemicals, as well as various types of bacteria causing a significant deficit of drinking water, which is very much needed for life. Fortunately, recent years have shown that thanks to the development of material engineering and nanotechnology, we can fight this problem. Nanotechnology is an area that allows the production of various materials that have at least one dimension below 100 nm [1], thanks to which we can create new and better products that have improved biological, chemical and also physical properties [2]. One of the materials that can be used to obtain filtration materials is polylactide or poly (lactic acid), known as PLA. It is a natural, biodegradable, thermoplastic polyester produced in biotechnological processes from renewable sources, e.g. maize [3]. PLA fibers have excellent mechanical properties, high UV protection, low flammability, low refractive index [4]. However, thanks to the continuous development of material engineering, it is possible to modify the previously known properties of fibers. PLA fibers are a susceptible raw material for various modifications and zinc oxide is one of these nanoducts. ZnO is a semiconductor white solid belonging to group II - VI of the periodic table, characterized by an energetic break, which at room temperature is 3.37eV and increases with decreasing size of nanoparticles [5-7]. Zinc oxide is obtained by two methods, by roasting zinc ores or as a result of the reaction of burning zinc vapors [5]. ZnO is biocompatible which is its important advantage, and also has high antibacterial activity and drying properties [8]. One of the uses of this compound is its use in textiles characterized by unique physicochemical properties, in order to neutralize and destroy bacteria that can develop on medical dressings during wound healing [9-11]. The main purpose of the conducted research was to develop an appropriate structure of the nonwoven system and to select appropriate modification conditions in order to obtain a system characterized by a density gradient enriched with zinc oxide with adequate porosity. The filtration system was designed as a layered system made of nonwovens produced by means of the needling method and the filer method. Zinc oxide, which has bactericidal properties, has been applied to the nonwoven fabric in the form of an aqueous suspension. This solution was prepared by mixing well-concentrated ZnO with acrylic acid and a cross-linking agent, while the whole was subjected to a curing process using a photoinitiator.

2. METHODOLOGY

Air permeability was carried out in accordance with PN-EN ISO 9237
Water permeability was determined based on the measurement of the flow time of 100 cm^3 of water through a non-woven disk with an area of 70 mm^2 placed in the foot of the filter system.
Protective properties against UV radiation (UPF) made in accordance with PN-EN 13758-1 + A1: 2007 on UV-VIS-NIR jasco V-670 spectrometer with Ulbricht's sphere

3. MATERIALS

The nonwoven structure has been produced by a classical nonwoven technique in which the pile is formed from staple fibers of a biodegradable PLA material by a carding system. For the formation of nonwovens, fibers with a linear weight of 6.84 den with a strength of 3.8 cN/tex and a relative elongation of 48% were used. The machine was fed with fiber in the amount of 30 g / field of the supply ladder and an elementary web was created with a surface mass of 9.8 g/m^2. The elementary run was assembled to obtain a surface mass of 150 g/m^2. The final nonwoven fabric was obtained by combining four layers of elementary weather. Nano zinc oxide (nano ZnO) was a commercial product of Aldrich (<200nm), while the additive concentrations used are in line with the experimental design procedure.

4. ANALYSIS

4.1 Water permeability

In order to determine which of the nonwovens obtained have better water permeability properties, they were subjected to a test to examine the time required for 100 cm^3 to flow through a 70 mm^2 nonwoven. The table 1 presents the average values of the results obtained for a given research material.

Table 1. Time values of flows in seconds of 100 cm^3 of water through a sample of 70 mm^2 of samples of PLA non-woven fabrics modified with acrylic resin containing ZnO for different values of needled.

concentration of acrylic resin [%]	concentration of zinc oxide [%]	needled 20	needled33	needled95
0	0	94	73	42
1	1	10	10	34
2	2	7	7	39
1	2	7	17	3
2	1	7	19	59
1.5	0.5	2	8	36
1.5	2.5	21	10	43
0.5	1.5	10	3	36
2.5	1.5	8	19	23
1.5	1.5	15	8	39

Analyzing the above table, we can notice that the level of the stinging and also the concentration of resin and ZnO directly affect the time needed for the passage of water. With the increase in the value of the scrubbing, the water flow time decreases for nonwoven fabrics not modified with acrylic resin, which may be the result of the increase of transversely oriented fibers in the nonwoven PLA structure. The introduction of a hydrophilic modifier, crosslinked acrylic acid, into the nonwoven structure increases the water flow time. This effect may result from the phenomenon of sealing the nonwoven structure by water swelling cross-linked acrylic acid.

4.2 Air permeability

In order to determine the air permeability, the test specimens were subjected to the test consisting in passing air through the material. The table 2 presents the average values of the results obtained for a given research material.

Table 2. Air permeability in mm/s for non-wovens PLA modified with acrylic resin containing ZnO for different values of the needled.

concentration of acrylic resin [%]	concentration of zinc oxide [%]	needled 20	needled 33	needled95
0	0	450	520	487
1	1	528	537	512
2	2	607	535	500
1	2	831	610	598
2	1	537	639	601
1.5	0.5	708	645	630
1.5	2.5	557	710	511
0.5	1.5	577	712	725
2.5	1.5	605	588	602
1.5	1.5	567	632	556

Analyzing the results shown in table 2, one can observe the phenomenon of decreasing the air permeability along with the increase of the resin content while increasing the content of nano ZnO.

4.3 Protective properties against UV radiation (UPF)

In order to determine the blocking of UV rays and photocatalytic properties of ZnO, being a modifying agent of PLA nonwoven, studies have been carried out to determine the protective effect against UV radiation. The table 3 shows the results of the study.

Table 3. Protective properties against UV radiation of non-wovens PLA modified with acrylic resin containing ZnO for different values of the needled

concentration of acrylic resin [%]	concentration of zinc oxide [%]	needled 20	needled 33	needled95
0	0	4	12	4
1	1	91	24	10
2	2	104	59	17
1	2	49	32	82
2	1	54	10	10
1.5	0.5	12	6	9
1.5	2.5	45	66	73
0.5	1.5	15	45	37
2.5	1.5	23	44	30
1.5	1.5	48	43	20

Analyzing the above table, we can conclude that the addition of zinc oxide to the structure of the tested material influenced the improvement of protective properties and, consequently, confirmed the presence of ZnO.

5. CONCLUSIONS

The non-wovens produced from the biodegradable PLA fiber were subjected to a modification of the performance by introducing into the ZnO nano structure. Nano particles were immobilized on the surface of the fibers by in situ photopolymerization using a cross-linking agent. The use of this method allows for permanent modifications, resistant to mechanical forces. The introduction of an acrylic resin, acrylic acid, into the nonwoven structure increases the water flow time which may adversely affect applications as a filter material for water applications. At the same time, a reduction in air permeability is observed for nonwovens containing a higher proportion of the filler nano. The analysis of the UPF value allows qualitatively to identify the presence of ZnO nano in the structures of the nonwovens produced.

6. REFERENCES:

1. Kosmala K., Szymańska R.; Nanocząsteczki tlenku tytanu (IV). Otrzymywanie, właściwości i zastosowanie, *Kosmos*, 2016, 235-245
2. Piecyk L., *Tworzywa Sztuczne i Chemia 2*, 2006, 20
3. Plackett D., Vázquez A., Natural polymer sources, *Green Composites Polymer Composites and the Environment,* 2004, 123-153
4. Patra AK, Pattanayak AK. Novel varieties of denim fabrics, *Denim: Manufacture, Finishing and Applications. Woodhead Publishing Series in Textiles*, 2015, 483-506
5. Żelechowska K., *Nanotechnologia w praktyce*, PWN, Warszawa 2016
6. Mirzaei H., Darroudi M., Zinc oxide nanoparticles: Biological synthesis and biomedical applications, *Ceramics International*, 2017, No.43, 907-914
7. Kuo, C.-L., Wang, C.-L., Ko, H.-H., Hwang, W.-S., Chang, K.-m., Li, W.-L., Huang, H.-H., Chang, Y.-H., Wang, M.-C., Synthesis of zinc oxide nanocrystalline powders for cosmetic applications, *Ceramics International*, 2010, No.36, 693-698
8. Teterycz H., Suchorska-Woźniak P., Fiedot M., Karbownik I., Deposition of Zinc Oxide on the Materials Used in Medicine. Preliminary Results, *FIBRES &TEXTILES in Eastern Europe* 2014, No.22, Vol.3(105), 126-132
9. Kubiak T., Wykorzystanie pokryć z poli(glikolu etylenowego) i chitozanu do zapewnienia biokompatybilności nanocząstkom w aplikacjach biomedycznych, *Polymers in Medicine* 2014, No.44, Vol.2, 119-127
10. Butkus, M. A., Edling L., Labare M. P., The efficacy of silver as a bactericidal agent: advantages, limitations and considerations for future use, *J. Water Supply Res. Technol. AQUA*, 2003, No.52, 407-416.
11. Bojarska M., Szwast M., Jakubiak Sz., Michalski J., Gradoń L., Membrany polimerowe modyfikowane tlenkiem cynku – metoda wytwarzania, *Inżynieria i Aparatura Chemiczna*, 2013, No.52, Vol.6, 521-522