International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:9, No:10, 2015

Two and Three Layer Lamination of Nanofiber

Roman Knizek, Denisa Karhankova, Ludmila Fridrichova

***Abstract*—**For their exceptional properties nanofibers, respectively, nanofiber layers are achieving an increasingly wider range of uses. Nowadays nanofibers are used mainly in the field of air filtration where they are removing submicron particles, bacteria, and viruses. Their efficiency is not changed in time, and the power consumption is much lower than that of electrically charged filters. Nanofibers are primarily used for converting and storage of energy in both air and liquid filtration, in food and packaging, protecting the environment, but also in health care which is made possible by their newly discovered properties. However, a major problem of the nanofiber layer is practically zero abrasion resistance; it is, therefore, necessary to laminate the nanofiber layer with another suitable material. Unfortunately, lamination of nanofiber layers is a major problem since the nanofiber layer contains small pores through which it is very difficult for adhesion to pass through. Therefore, there is still only a small percentage of products with these unique fibers 5.

***Keywords*—**Nanofiber layer, nanomembrane, lamination, electrospinning.

I. Introduction

INSPIRATION for lamination of nanofiber layers with other mainly textile material can be found in outdoor clothing [3]. The reason for the inspiration in this industry is that most of the upper outdoor clothing includes a membrane, which is used to achieve high hydrostatic resistance, high vapor permeability and wind resistance. Emphasis is placed not only on the excellent properties of the garment as well as their combinations, which must be in the correct layering.

- At the first (underwear) and a second layer (sweatshirt) is important especially good water vapor permeability.
- The second layer should fulfill high water vapor permeability, but also a good thermal isolation.
- The third layer (jacket) should fulfill all requirements for the lower layer and also waterproof and windproof [12], [13].

To achieve the desired parameters at the third layer, it is necessary for its production to use so-called multi-layer fabrics. It is, therefore, necessary to select and laminate in one all suitable layers–the material with waterproof form or coating, or material with membrane eventually with membrane and with lining. Currently, there are a plethora of materials, membranes on the market. It is often very difficult for the garment manufacturer to choose a suitable combination [14], [15]. If he chooses peak membrane and the surface material, the resulting combination may not always be ideal. This is primarily caused by the lamination method, using the correct chemical composition of the solution for coating laminating points, etc. Therefore, the question arises, how will lamination worse the resulting evaporative resistance of the whole sandwich [5], [6].

The suitability of nanofiber membranes, as shown in Fig. 1, for different applications, is determined by their morphological structure and physical properties. Currently, microporous membranes can be applied in many areas of human holding. Inner Fibrous pore morphology, average fiber morphology, and permeability belong among the most important structural parameters of nanofiber membranes. These membranes also have due to their great ratio of surface area (volume and length) the large and specific surface.

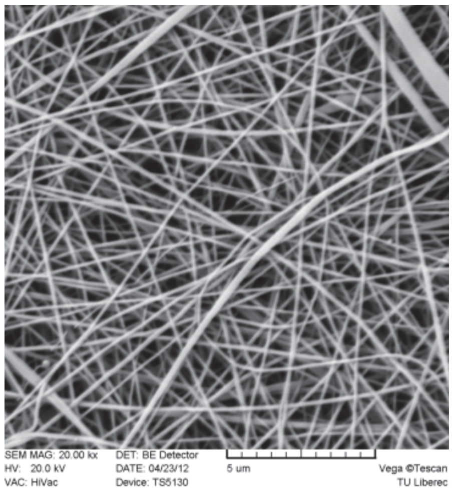

Fig. 1 Nanofiber membrane

Thanks to this remarkable fact they can be found, e.g., in medicine application - in tissue engineering, as an absorbent of extraction of solids or in the industry in air filtration. An interesting feature of nanofiber membranes is their air permeability and water vapor permeability. Based on the research in the area of nanofiber layers and their suitable applications for industrial use a completely new nanofiber membrane was managed to develop, Fig. 2. This new membrane has the aforementioned features: waterproof, wind resistance and permeability. The great advantage of nanofibrous layers is their easy producing on production devices called Nanospider (developed at TUL). This membrane must be laminated on a woven or knitted fabric [4], [8], [10], [11]. However, for industrial use also a nonwoven fabric, mainly due to the low price, should be considered. The aim is to create two, two and a half and three-layer laminates in order to achieve high resistance to abrasion while

R. Knizek and L. Fridrichova are with the Technical University of Liberec, Faculty of Textile Engineering, Department of Textile Evaluation, Studentska 2, 461 17 Liberec, Czech Republic (e-mail: roman.knizek@tul.cz, ludmila.fridrichova@tul.cz).

D. Karhankova, the Technical University of Liberec, Faculty of Textile Engineering, Department of Textile Evaluation, Studentska 2, 461 17 Liberec, Czech Republic (e-mail: denisa.karhankova@tul.cz).

maintaining the high functional value of nanofiber layers [7], [9].

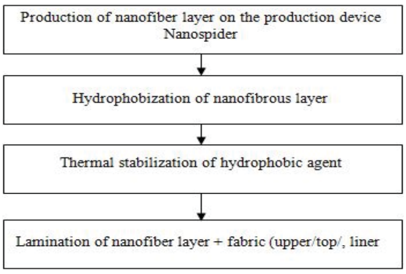

Fig. 2 The principle of production the layered laminate

II. Experiment

A nanofiber layer weighing 2 and 4 g/m^2 was produced through electrostatic spinning on the production device of the type NanospiderTM, Fig. 3, using the spinning electrode, comprising the spinning elements in the form of strings of EP 2173930. During production, it was deposited on the backing fabric (spunbond). During electrospinning, the distance between the spinning elements of the spinning electrode and the backing fabric was 15 cm, and the difference voltage between the crimping electrode and the collecting metal plate was 70 kV. As a starting polymer for the nanofiber layer PA6 was applied.

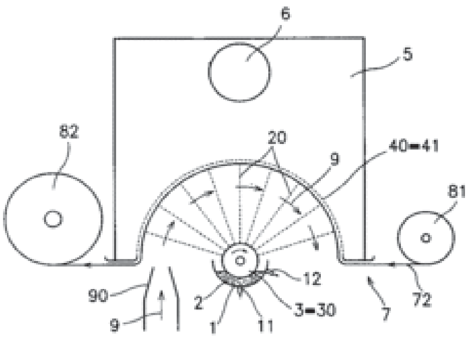

Fig. 3 NanospiderTM, Nanospider equipment for production of nanofibers by electrostatic spinning

A. Lamination of Nanofiber Membranes

The actual nanofiber layer is laminated with a selected material (two-layer laminate), or the membrane lamination is performed between two selected materials and a three-layer laminate is created. You may also consider printing of the two- layer laminate and so give rise to two-and-a-half-layers laminate. In order to develop a laminate, it is necessary to apply polymeric points to the backing material using gravure method. Such laminates protect the nanofiber layer against mechanical damage [1], [2].

B. Lamination Points

In order to develop a laminate, it is necessary to create lamination points, as shown in Fig. 4. These points are created in gravure manner and as a binder powder adhesive with particles size between 80-200 micron is used, in particular for the gravure of printing cylinders with a density of 11 to 17 mesh. The skimming itself takes place in a conventional manner.

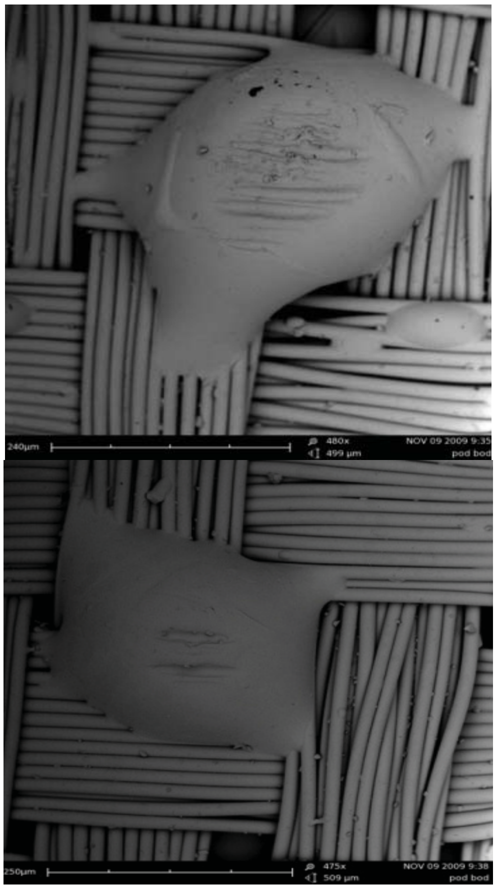

Fig. 4 A polymeric point formed on the fabric during application

III. Production of Two-Layer, Two and A Half and Three- Layer Laminates

A. Two-Layer Laminate

As already mentioned during production the nanofiber membrane is deposited on the backing fabric (e.g. spun bond nonwoven fabric, Cerex or baking paper). To the side of the nanofiber membrane, before passing through the lamination machine, the upper material with lamination points is applied and, under defined conditions, the actual lamination occurs. As a lamination machine, the machine brand Kannegiesser was used. After lamination, the backing fabric is subsequently removed, Fig. 5.

B. Three-Layer Laminate

Prior to the passage through the lamination machine the top or lining material is attached to the nanofiber membrane, and under defined conditions, the lamination is carried on. After lamination, the ground fabric is removed. Next, the second material is attached, depending on where the laminated

International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:9, No:10, 2015

membrane is, and then re-lamination under defined conditions will take place. Fig. 6 shows a three- layer laminate.

C. Two and A Half Layers Laminate

Two and a half layers laminate is a brand name, in fact it is a three-layer laminate (upper fabric + membrane + printing etc.). It is recommended that footnotes be avoided (except for the unnumbered footnote with the receipt date on the first page). Instead, try to integrate the footnote information into the text.

This is a lamination of the upper fabric with membrane and to protect the membrane, instead of lining, printing is applied. The advantage, as already mentioned above, is lower basis weight compared to the three-layer laminate, but at the same time, it protects the membrane from the friction which arises during use, unlike the two-layer laminates. It is, of course, necessary to say, the protection of the membrane by printing is lower than with the lining. Such a laminate is suitable for activities such as cycling or running; it is not designed for shipping purposes. However, for better orientation, we will use the commercial designation of two and a half layers laminate, Figs. 7 and 8.

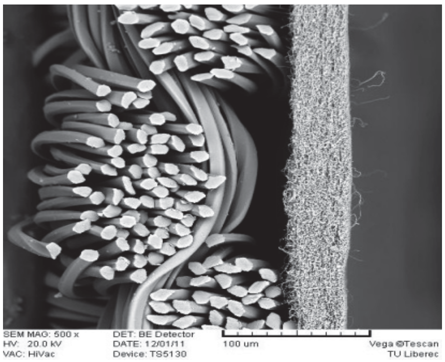

Fig. 5 Two-layer laminate

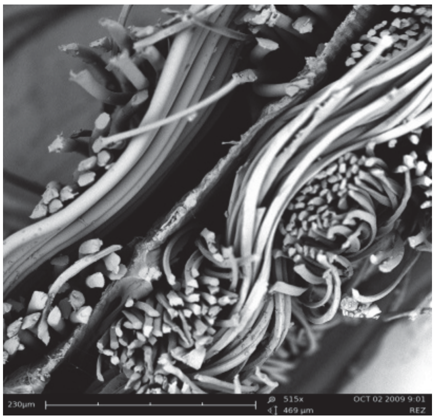

Fig. 6 Three-layer laminate

Designs for printing were created in the program Corel Draw 16. Tables of 200x200 mm were designed for the corresponding percentage to the covering of the printing area; Table I. Printing was carried out on carousel machines. We can see the longitudinal view of two and a half layers laminate (nanofibers membrane), Fig. 9.

IV. Evaluation

For the lamination of nanofiber layers, polypropylene spun bond was chosen. The reason for choosing this material is low cost and easy availability. The results show that the actual resistance of the nanofiber layer against abrasion from either side is zero. For the two layer laminates it is also zero, though Martindale was performed from the nanofiber layer, but if carried out from the nonwoven fabric side, it will reach 10,000 revolutions, and thus even the resistance of the nonwoven fabric. At two and a half layers laminate, the resistance of the nanofiber layer was 5000 rpm, which is a very good value. The covering of the nanofiber layer by printing was 30%. In three layers laminate, we reached the resistance of 10 000 rpm since the very nanofiber layer was laminated between two nonwoven textiles. Of course, air permeability and vapor permeability were deteriorated.

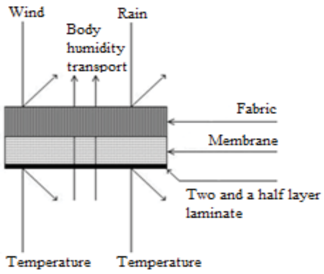

Fig. 7 Schematic representation of two and a half layers laminate

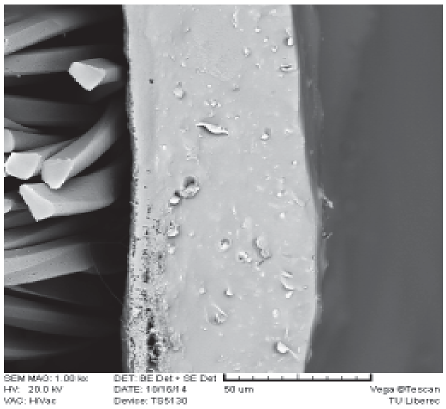

Fig. 8 Two and a half layers laminate

TABLE I
THE COVERING OF THE PRINTING AREA

Type of textile	Backing material	Covering the surface by printing [%]
Two-layer laminate	Fabric	26,8 ~ 27
Two-layer laminate	Fabric	43,3 ~ 43

There are, however, many sectors where it might not be a problem, as some types of filtration or membranes with nanofibers. It is possible to increase resistance to abrasion using other material or apply a much finer material to maintain the high breathability and water vapor permeability. Following are the results of these tests.

TABLE II
THE RESULTS OF MEASUREMENTS A NANOFIBER LAYER WEIGHING 2 g/m^2

2 g/m^2	Air Permeability [l/m^2/s]	Water Vapour Permeability Ret [Pa.m^2/W]	Martindale [rpm]
Spunbond	-	1,0	10 000
Nanofiber layer	-	0,0	0
2L	6,80	1,3	0
2,5L	3,18	2,4	5 000
3L	0,19	2,5	10 000

Measured according to Air Permeability: EN 9237, Waper Vapor Permeability: ISO 11902, Martindale: ISO 12947.

TABLE III
THE RESULTS OF MEASUREMENTS A NANOFIBER LAYER WEIGHING 4 g/m^2

4 g/m^2	Air Permeability [l/m^2/s]	Water Vapour Permeability Ret [Pa.m^2/W]	Martindale [rpm]
Spunbond	-	1,0	10 000
Nanofiber layer	-	0,0	0
2L	5,30	1,3	0
2,5L	3,01	2,4	5 000
3L	0,0	2,5	20 000

Measured according to Air Permeability: EN 9237, Waper Vapor Permeability: ISO 11902, Martindale: ISO 12947.

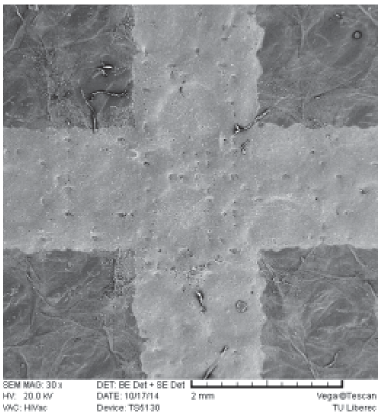

Fig. 9 The printing area on nanofibers

That increasing covering of the nanofiber membrane by printing reduces vapor permeability, as well as air permeability. However, no influence of printing on hydrostatic resistance was observed. Abrasion was measured by Martindale, and the print itself withstood rotation speed more than 10,000 rpm. Nevertheless, at 20% covering of the nanofiber membrane with print, a decrease of the nanofiber layer was observed from 1,000 rotations, at 30% it was at 3,000 rpm and at 40% at about 5,000 rpm, while at the competitive membrane there was not observed any decrease of the membrane. But the print design of the competitive membrane was very different, or more precisely, its line thickness was much smaller than that of the nanofiber, where the lines were significantly thicker, and thus printing was not spread on the membrane as it was on the competitive membrane.

V. CONCLUSION

We managed to create successfully two, two and a half and three-layer laminates that can protect the nanofiber layer against abrasion. Since the pores of the nonwoven fabric are far greater than the pores of the nanofiber layer, we can assume that the actual properties of the nanofiber layer will not be deteriorated, this is particularly true for filter purposes, but for a small resistance, the nanofiber layer cannot be used alone.

ACKNOWLEDGMENT

The research has been supported by the Department of Textile Evaluation, Technical University of Liberec.

REFERENCES

[1] TUL: *Method of production of nanofibres from the polymer solution by electrostatic spinning and equipment to perform the way* CZ Patent 294,274, 2003-2421, 2013.
[2] O. Jirsak, F. Sanetrnik, D. Lukas, V. Kotek, L. Martinova, J. Chaloupek, *A Method of Nanofibres Production from a Polymer Solution Using Electrostatic Spinning and a Device for Carrying Out the Method*. EP 1673493, 2006.
[3] L. Hes, P. Sluka, Introduction to the comfort of textiles, Technical University of Liberec, 2005.
[4] T. Heinish, V. Bajzik. , R. Knizek, Effect of the process of lamination microporous nanofiber membrane on the evaporative resistance of the two-layer laminate, *Advanced Materials Research,* 677, 103-108, ISSN: 10226680, 2013.
[5] P. W. Gibson, Factors Influencing Steady-State Heat and Water Vapor Transfer Measurements for Clothing Materials, *Textile Research Journal*, Vol. 63 no. 12, 749-764, 1993.
[6] P. Gunavathi, Characterization of nanomembrane using nylon/6 and nylon/6 polye (e- caprolactine) blend, *Indian Journal of Fibre &Textile Research,* 201-306, 2012.
[7] D. Reneker, I. Chun, Nanometre diameter fibres of polymer, produced by electrospinning, *Nanotechnology*, 7, 215, 1996.
[8] R. Knizek. L. Fridrichova, V. Bajzik, Polyurethane coating on a supporting layer of polymeric nanofibers, *Advanced Materials Research*, 607, 31-35, ISSN: 10226680, 2013.
[9] J. A. Prince, D. Rana, T. Matsuura, N. Ayyanar, T. S. Shanmugasundaram, G. Singh, Nanofiber based triple layer hydro-philic/-phobic membrane - a solution for pore wetting in membrane distillation, *Scientific Reports,* 4, 6949, 2014.
[10] C. J. Luo, Simeon D. Stoyanov, E. Stride, E. Pelanb, M. Edirisinghe, Electrospinning versus fibre production methods: from specifics to technological convergence, *Chemical Society Reciews*, 41, 4708-4735, 2012.
[11] P. Gibson, H. Schreuder-Gibson, D. Rivin, Transport properties of porous membranes based on electrospun nanofibers, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, Vol. 187–188, 469–481, 2001.
[12] Hohenstein Institute, Clothing physiological research in the service of wear comfort, *H.I. Germany*, Editor. 2009.
[13] L. Hes, Fundaments of design of fabrics and garments with demanded thermophysiological comfort, *International Round Table, Clothing Comfort – Condition of Life Quality*, 2009.
[14] J. E. Ruckman, R. Murray,H. S. Choi, Engineering of clothing systems for improved thermophysiological comfort:The effect of openings. *International Journal of Clothing Science and Technology*,37-52, 1999.
[15] F. Kar,J. Fan, W. Yu, X. Wan, Effects of thermal and moisture trasnprt properties of T-Shirton wearers comfort sensations. *Fibers and and Polymers*, Vol. 8, Number 5, 2007.