

## EFFECT OF HOT-PRESSING ON PROPERTIES OF BUBBLE-ELECTROSPUN NANOFIBER MEMBRANE

by

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*Polyurethane nanofiber membranes were prepared by the bubble-electrospinning. The membranes were used to make a composite fabric with two plain nylon fabrics. The morphology of nanofiber membranes, the air permeability and the peel strength of the composite fabrics were investigated experimentally. The results obtained in this paper can be used for optimization of nanofiber membranes.*

Key words: *bubble-electrospinning, polyurethane, nanofiber membrane, composite fabric*

### Introduction

Clothing helps the human body adjust its physiological functions according to environment, and balances the heat exchange between human body and environment. Therefore, clothing enhances the physical, physiological, and psychological comfort, and broadens the activity area of humans [1]. With the development of clothing, peoples put forward more and more functions on the fabrics, such as water-oil repellent, breathable. Lamination is an increasingly important technology for adding value to high-tech textiles. A laminated fabric consists of two or more layers, which can be a textile fabric, non-wovens and functional membranes. They bonded closely together by means of an adhesive, or by the adhesive properties of one or more of the component layers. The laminated fabric has the advantage of each material, enhances and extends the range of functional performance properties of textiles. Cheaper fabric structures may be coated or laminated to provide higher added value to end users and higher profit margins to manufacturers [2]. For example, the Gore-Tex fabric is made by bonding the Gore-Tex membrane with traditional fabrics, the artificial leather can be made by bonding suedette with woven or knitted fabrics. The adhesive can be used by the methods of spray coating, roller coating or adhesive film in the lamination. The adhesive plays a very important role on the air permeability which is a key factor of the comfortability of the laminated fabrics. The roller coating and adhesives film often cause bad air permeability [2].

The electrospun nanofiber membranes of polyurethane (PU) are highly porous and form ultra-lightweight components. In clothing they may therefore be more comfortable,

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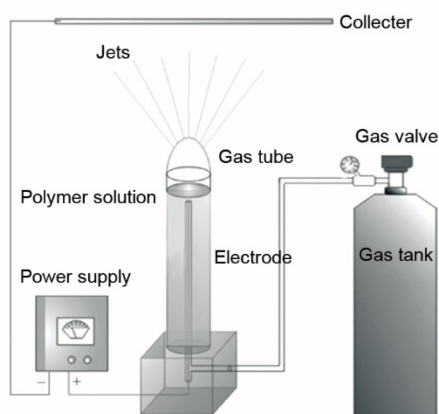
breathable, and waterproof. Many studies were carried out on the application of nanofiber membranes in the clothing [3-6].

Bubble-electrospinning [7-9] is a promising technology for mass production of nanofiber [10, 11], which use bubbles from polymer solutions or melts for fabricating nanofibers using electronic force. The nanofiber prepared by bubble-electrospinning is very small in size, and the preparation of the nanofiber membrane can be used for filtering, tissue engineering support, sensors, and protective clothing.

In this paper, nanofiber membranes of hot-melt PU were prepared by the bubble-electrospinning, and the membranes were used to make laminated fabrics by hot-pressing at 70, 80, 90, and 100 °C, respectively, as a novel adhesive film. The effect of hot-pressing temperature on air permeability and peel strength of the laminated fabrics were studied. The research results will be helpful for development of high-tech composite fabrics.

## Experimental

The polymer, PU, was purchased from Nantong Tenglong composite fabric Co., Ltd., Nantong, China. The melt point is 90 °C. The solvents, dimethyl formamide (DMF) were bought from Sinopharm Chemical Reagent Co., Ltd., Beijing. All the chemicals were used as received. The polymer was added into DMF, and then the mixture was stirred at room temperature for four hours to get homogeneous and transparent solution. The PU solution concentration was 8 wt.%.



**Figure 1. Bubble-electrospinning equipment set-up**

The spinning process was performed on the bubble-electrospinning equipment (Nantong Bubbfil Nanotechnology Co., Ltd., Nantong, China). The bubble-electrospinning equipment set-up is shown in fig. 1.

The bubbles of polymer solution were blown by the nitrogen gas, and the bubbles were stretched in the electric field. A flat piece of aluminum foil placed 10 cm above the nozzle was used for collecting fibers. The voltages applied to the electrode were set as 20 kV. The experiments were carried out at room temperature, 37 °C, and 65% relative humidity. The spinning time was 20 minutes for a sample.

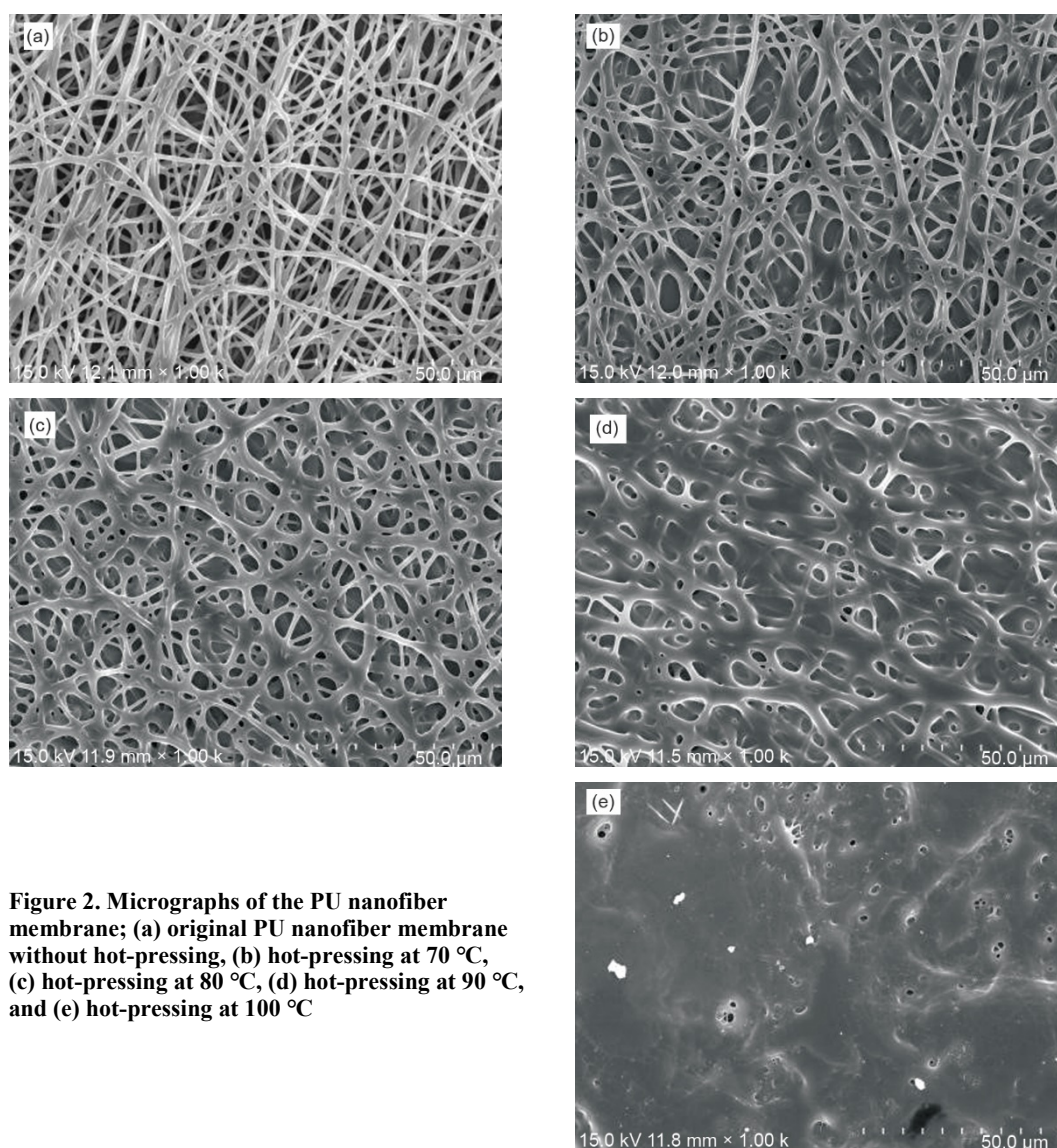
The samples for air permeability test and peel-off test were sandwich composite fabrics prepared by hot-pressing two plain nylon fabrics and a nanofiber membrane. The nanofiber membranes for morphology investigation were hot-pressed between two release papers.

The morphology of the obtained nanofiber membranes was determined by a scanning electron microscope (S-4800, LaB6 gun, Kevex X-ray EDS, Hitachi, Tokyo). The hot-pressing was carried out by a hot-press machine (NHG-500B, Jiatian, Shanghai), the temperatures were 70, 80, 90, and 100 °C, the pressure was 0.1 MPa. The air permeability was tested by fully automatic fabric air permeability tester [YG(B)461E, Darong] according to ISO9237:1995 (Textiles – Determination of permeability of fabrics to air). The peel-off test was carried out by universal testing machine (5960 Dual Column Tabletop Testing Systems,

Instron, Norwood, Mass, USA) according to JIS L1089:2007 (Testing methods for laminated fabrics), the test sample size is 25 × 150 mm.

### Results and discussion

Figure 2 shows the morphology of the PU nanofiber membrane. Compared with the original nanofiber membrane in fig. 2(a), the hot-pressed PU nanofiber membranes were melted on different levels. With the rise in temperature, the degree of melting increase is shown in figs. 2(b), (c), (d), and (e). In fig. 2(e), almost all of the PU nanofiber melted and there is only a few of small hole on the membrane.



**Figure 2.** Micrographs of the PU nanofiber membrane; (a) original PU nanofiber membrane without hot-pressing, (b) hot-pressing at 70 °C, (c) hot-pressing at 80 °C, (d) hot-pressing at 90 °C, and (e) hot-pressing at 100 °C

The air permeability and peel strength of the PU nanofiber membrane composite fabrics were shown in figs. 3 and 4. In fig. 3, with the rise in temperature, the air permeability decrease, the peel strength increase. As shown in fig. 2(b), although the pressing temperature 70 °C, the PU nanofiber melted visibly, some open-holes were blocked with the melting, therefore the air permeability of the PU nanofiber membrane decreased. When the temperature was over the melt-point 90 °C of the PU, most of the nanofibers melt, then the open-holes decreased, especially at 100 °C, the nanofiber membrane became a membrane with a few of small hole, therefore the air permeability was very low that can not be measured and the peel strength significant increased.

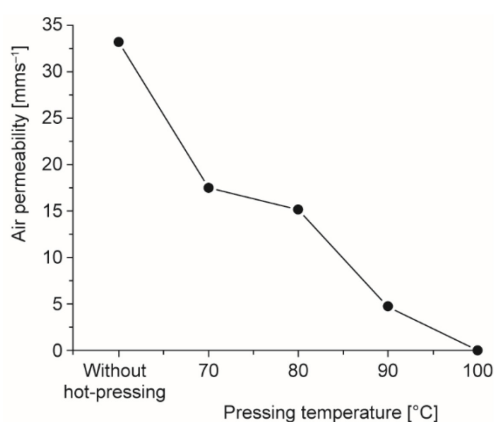


Figure 3. Air permeability of the PU nanofiber membrane composite fabrics

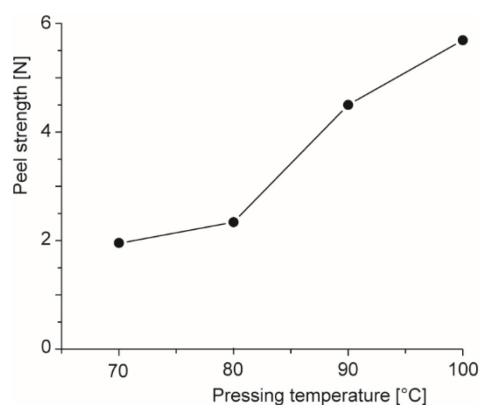


Figure 4. Peel strength of the PU nanofiber membrane composite fabrics

## Conclusion

The PU nanofiber membranes were obtained by bubble-electrospinning, then the membranes were used to make sandwich composite fabrics by hot-pressing. The morphology of the membrane and the air permeability and peel strength of the composite fabrics were investigated. The PU nanofiber melted at all test temperature, with the rise in temperature, the degree of melting increased. With the melting, some open-holes were blocked, the air permeability of the composite fabrics decreased. When the temperatures were 90 and 100 °C, most of the nanofibers melt, the air permeability was very low that can not be measured and the peel strength significant increased.

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## References

- [1] Gugliuzz, A., Drioli, E., A Review on Membrane Engineering for Innovation in Wearable Fabrics and Protective Textiles, *Journal of Membrane Science*, 446 (2013), Nov., pp. 350-375
- [2] Singha, K., A Review on Coating and Lamination in Textiles: Processes and Applications, *American Journal of Polymer Science*, 2 (2012), 3, pp. 39-49

- [3] Lee, S., *et al.*, The Effects of Laundering on the Mechanical Properties of Mass-Produced Nanofiber Web for Use in Wear, *Textile Research Journal*, 79 (2009), 12, pp. 1085-1090
- [4] Gorji, M., *et al.*, Fabrication and Characterization of Polyurethane Electrospun Nanofiber Membranes for Protective Clothing Applications, *Journal of Applied Polymer Science*, 125 (2012), 5, pp. 4135-4141
- [5] Hong, K. A., *et al.*, Effect of Waterborne Polyurethane Coating on the Durability and Breathable Waterproofing of Electrospun Nanofiber Web-Laminated Fabrics, *Textile Research Journal*, 85 (2015), 2, pp. 160-170
- [6] Hae, A. W., *et al.*, Waterproof and Breathable Properties of Nanoweb Applied Clothing, *Textile Research Journal*, 81 (2011), 14, pp. 1438-1447
- [7] He, J.-H., *et al.*, Review on Fiber Morphology Obtained by Bubble Electrospinning and Blown Bubble Spinning, *Thermal Science*, 16 (2012), 5, pp. 1263-1279
- [8] He, C. H., *et al.*, Bubbfil Spinning for Fabrication of PVA Nanofibers, *Thermal Science*, 19 (2015), 2, pp. 743-746
- [9] Li, Y., *et al.*, Bubbfil Electrospinning of PA66/Cu Nanofibers, *Thermal Science*, 20 (2016), 3, pp. 993-998
- [10] Chen, R. X., *et al.*, Mini-Review on Bubbfil Spinning Process for Mass-Production of Nanofibers, *Materia*, 19 (2014), 4, pp. 325-343
- [11] Chen, R. X., *et al.*, Bubbfil Spinning for Mass-Production of Nanofibers, *Thermal Science*, 19 (2014), 5, pp. 1718-1719

