Applied Surface Science 342 (2015) 101–105

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Effect of surface modifications on the thermal and moisture behavior of wool fabric

Xin Wang[a,*], Yuan Zhao[b], Wenbin Li[b], Hao Wang[c]

[a] Centre for Advanced Materials and Performance Textiles, School of Fashion and Textiles, RMIT University, Melbourne 3056, Australia
[b] School of Textile Science and Engineering, Wuhan Textile University, Wuhan 430200, China
[c] Centre of Excellence in Engineered Fibre Composites, University of Southern Queensland, Toowoomba 4350, Australia

ARTICLE INFO

Article history:
Received 7 December 2014
Received in revised form 5 March 2015
Accepted 6 March 2015
Available online 14 March 2015

Keywords:
Surface modification
Wool fabric
Thermal resistance
Moisture resistance
Temperature
Humidity

ABSTRACT

Thermal and moisture behavior is crucial in determining the comfort of clothing. Surface modification of fibers brings new functions and properties to fibrous materials, but the comfort of the as-made clothing changes accordingly due to different thermal and moisture behaviors. In this study, physical and chemical modifications have been conducted to wool fabric to investigate their effects on the thermal and moisture behaviors of clothing. Surface wettability, wicking properties, thermal and moisture resistance together with surface temperature and humidity of the microclimate have been tested. It has been found that the wettability of wool fabric is greatly improved and wicking properties are granted to the fabric. Higher thermal and moisture resistance have been noticed for the treated wool fabric. The treated fabric shows longer moisture liberation process and the surface temperature and humidity varies in a different way compared with untreated fabric. Understanding the thermal and moisture behaviors of fabric after surface modification would benefit the further development of surface functionalizing technology and design of next to skin clothing.

1. Introduction

Considering the usage of clothing, interaction between humane skin and clothing itself is crucial in determine the sensation and comfort of wearer [1,2]. As sweating is always happening and it reacts with the clothing of the wearer, the moisture content, surface temperature, surface humidity and thermal/moisture transfer of clothing are subject to instant changes. It is a complicated case when the clothing in service with higher amount of sweating such as sporting, walking in hot weather and so on. The sweat needs to be transferred swiftly by the clothing to cool the body, in which the water/moisture absorbing properties is important. On the other hand, the clothing must prevent excessive heat loss to cause a chilling feeling to body under windy conditions. The materials, structure of the clothing, environment conditions, the sweating level and the sensation of wearer affect the comfort of clothing. To improve the comfort of clothing for hot weather or sports, careful selection of materials and clever design is essential to fulfill the requirements from consumers [3]. In order to understand the thermal and moisture behavior of clothing, different assessment methods have been developed [4–10]. These assessment methods include the moisture management tester [4], thermal resistance and moisture resistance [5], sweating manikin [6], thermophysiology [7], model [8], etc. However, most of these tests are conducted in a static condition in which the real moving conditions of clothing in service have not been taken into consideration.

Surface modification has been proved to a useful approach to functionalize fibrous materials with improved performance to its original products. Wool fibers have a long history of surface modification to achieve extra value or feature. Surface modification, such as chemical treatment, plasma treatment, coating and surface functionalization, is essential in the finishing process of wool products to achieve whiteness, anti-yellowing, insect-resistance, dimension stability, antistatic property, flame-retardancy and photostability [11]. Attention has been put on the shrinkproof aspect of wool as which is important in wool products in cold weather [12,13]. Surface wettability has been achieved as well to develop wool products in next to skin products in summer [14,15]. As the surface properties affect the contacts between fibers/fabric and moisture/water, thermal and moisture behavior of the fabric will definitely be changed after surface modification. Consequently the comfort of the clothing will be different. However, few attentions have been put on this topic so far.

Based on the previous work on the development of thermal and moisture assessment of dynamic moisture liberation [16,17], this

* Corresponding author. Tel.: +61 3 9925 9418.
E-mail address: wangxin0222@hotmail.com (X. Wang).

http://dx.doi.org/10.1016/j.apsusc.2015.03.027
0169-4332/

work focuses on thermal and moisture behavior of wool fabrics in the whole process of the interactions between water and the fabric from the contact stage to the wicking of water inside fabric and then to the thermal and moisture transfer followed by the moisture liberation. The surface modifications, both physical and chemical ones, affect the thermal and moisture behavior directly. The comfort of resultant fabrics would be totally different which further benefit the design and development of sportswear from wool fibers.

2. Experimental

2.1. Materials

Wool twill fabrics (Fig. 1a, serge, 270 g/m^2 and 200 g/m^2) were provided by the No.3 Wool Factory of Lanzhou, China. Samples for treatment were prepared in the size of 35 cm × 15 cm. All the samples were washed in deionized water, then dried and conditioned at conventional conditions (temperature 20 °C and relative humidity 60%).

Hydrogen peroxide (30%), sodium carbonate and sodium silicate were chemical grade, purchased from Shanghai Chemical Reagents Co. Ltd. Shanghai, China.

2.2. Surface modifications

2.2.1. Corona discharge

Corona discharge treatment was conducted using a 6 kW glow discharge generator (SDCD16-2-10, manufactured by Dalian Number Nine Electronic Incorporation, Dalian, China) with treating speed 2 m/min in the presence of air. As shown in Fig. 1b, high voltage was applied between the wire electrode and PVC electrode (the gap between electrodes was 8 mm). A violet light was observed with brushlike discharges treated on the fabric during the treatment. The discharge voltage was set as 12 kV, and the number of passage was three.

2.2.2. Hydrogen peroxide treatment

For hydrogen peroxide treatment, wool fabrics were treated in an aqueous bath with a liquid to fabric ratio of 25:1, as shown in Fig. 1c. Hydrogen peroxide concentration was set as 12% and the solution contained 0.2% (w/w) sodium carbonate and 0.7% (w/w) sodium silicate. The bath temperature was controlled as 50 °C and the treating time was 1 h. Hydrogen peroxide concentration was changed while other parameters were kept the same to investigate its effect on properties of the treated wool fabric.

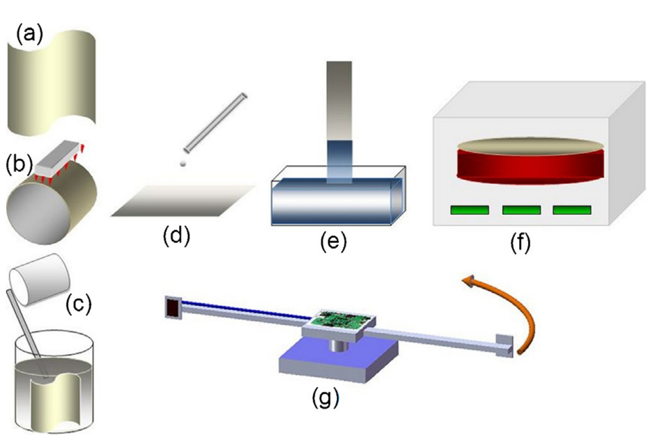

Fig. 1. Schematics of experimental details. (a) Wool fabric; (b) corona discharge treatment; (c) hydrogen peroxide treatment; (d) water absorbing time measurement; (e) wicking height measurement; (f) thermal and moisture resistance measurement; (g) dynamic surface temperature and humidity measurement.

2.3. Measurements and characterizations

2.3.1. Surface wettability

Fabrics were placed on a table to test the water absorbing time to reflect its surface wettability, 0.7 ml water was dropped using a syringe from 2 cm above the sample as shown in Fig. 1d. The time for the droplet to sink into the fabric was then recorded by a stop watch when there was no obvious mirror reflection on the wet mark. Every fabric was tested for five times and the results were averaged.

2.3.2. Wicking height

The wicking height of the samples was tested by suspending the fabric vertically above a reservoir of distilled water with its lower edge immersed in the water, as shown in Fig. 1e. The rate of rise of the leading edge of the water was monitored and a dye was added to the water to make easily detection of the position. The height from the water level to the top of the wet mark on the fabric was recorded as wicking height at every minute for 30 min.

2.3.3. Thermal and moisture resistance

A sweating guarded hotplate system (FY258B, manufactured by Ningbo Textile Instrument Factory, China) was used to measure the thermal resistance and moisture vapor resistance of fabric, as shown in Fig. 1f. The thermal resistance was evaluated by measuring the temperature and heat flux during the test while the moisture vapor resistance was tested by measuring the water vapor pressure and the evaporative heat loss [5].

2.3.4. Surface temperature and humidity

A purpose-built apparatus was designed to test surface temperature and humidity of fabric in the process of moisture liberation in the environment with a certain wind speed, as shown in Fig. 1g. A central measurement panel is mounted on a motor (rotating speed 240 rpm) to obtain the data of temperature and humidity from the sensors mounted on the surface of the sample. The panel consists of a data acquisition and transmission module, a control module and a power module. A shaft with a distance of 250 mm from the panel was applied to generate the rotating movement to the sample that was mounted on the testing platform at one end of the shaft. Fabrics were immersed in distilled water for a certain minutes (10 min for cotton and 30 min for wool) and dehydrated by centrifugal method to remove the residual water on the surface of the fabric. The data of temperature and humidity was transferred to the panel through the electric wire mounted on the shaft, and then to PC wirelessly.

During the test, the apparatus was first running in an unloaded state under a specific rotating speed for about 0–40 s, so as to measure the temperature and moisture of the environment, the data was then set as the standard point of the testing. Fabric with moisture regain of 85% was then loaded and the testing was running until the data of temperature reached to the standard point again to accomplish the equilibrium process. The data of temperature of the fabric was then recorded in this cycle.

3. Results and discussion

3.1. Surface wettability

Surface properties have been greatly modified after physical and chemical methods. The surface wettability affects the comfort of clothing directly as it determines the amount of absorbed sweat from body skin in service. According to previous studies [14,15], the surface morphology of wool fiber after corona discharge and hydrogen peroxide treatment has been severely etched and destroyed. The breakage of scale of wool fiber would change the surface properties and thus affect its interaction with water and moisture.