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Transport properties of fabrics treated with nano-wool fibrous materials

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Abstract

This paper reports on the characterization of the nano-wool fibrous materials that were obtained by using a patent pending technology to pulverise natural wool fibers into nano-scale particles in terms of morphology. After three steps pulverization, the nano-wool particles are in fibrous shape with length of around 80–300 nm, diameter of 10–80 nm and the mode particle size was around 100 nm. The surfaces of cotton fiber in a fabric treated with the nano-wool fibrous materials were covered a film of nano-wool fibrous materials, which change the water absorbency, thermal conductivity and Q_{max} values of the fabric significantly. These results indicate that the nano-wool fibrous materials can be used as a functional material for cotton fabrics treatment.

Keywords: Wool; Nano-particles; Fibrous materials; Functional performance

1. Introduction

Natural fibers have played an important role as textile materials from ancient times and still are widely used in the modern textiles industry for their unique properties as high quality textile materials. Not all natural fibers can be used to spin yarns, because of their short length. Consequently, natural fibers such as wool, silk, cotton or hemp are wasted during processing and final usages. A new way of reusing these fibers has large marketing potential because of their excellent intrinsic properties. Meanwhile, not only the textile industry, but many other industries like the bio-medical industries need such bio-compatible materials [1].

In this paper, we report the characterization of nano-wool fibrous material that was produced according to a patent pending technology to pulverise natural wool fiber into nano-scale particles, which can be used as an agent to treat pure cotton fabrics to obtain additional functions such as UV protection, IR absorption and warmth retention.

Many researchers have tried to establish new application areas for natural fibers by developing from them new materials for use in bio-technological and bio-medical fields. Yamad [2] proposed a process for the solubilisation of such hair and pointed out many extensive uses of animal hair. He mentioned that animal hair had been used as a trapping agent for heavy metals, an additive for cosmetic and food, a hair tonic and an improver for clothing. US Patent 5,853,764 described a way to manufacture super fine silk powder by using an alkaline aqueous solution [3], while US Patent 5,718,954 claimed a way to produce superfine silk powder with a particle size at the level of around 10 μm [4]. US Patent 4,233,212 claimed a method to crush silk fibers into fine powders to obtain powders particularly useful as an additive for cosmetic preparations [5]. CN 94115873.X disclosed a method to prepare nano-scale cellulose powder with an average size of 2.5–10 nm from cotton or hemp fibers by chemical treatment together with low temperature drying and pulverization and filtration. These US and CN patents reported specific methods to prepare fine/super fine powder from protein or cellulose fiber and suggested some potential applications, but none of them reported the technique to prepare nano-scale fibrous materials and characterization of its morphology and functional properties.

Wool is the fiber from the fleece of sheep. It is a natural, protein, multi-cellular staple fiber, composed of proteins and organic substances made from carbon, hydrogen, oxygen, nitrogen and sulphur [6,7]. The length of a wool fiber depends on the

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breed of sheep and the fiber's growing time. In general, wool fiber length ranges from 20 to 300 mm with a diameter in the range 8–50 μm [8]. In cross-section, a wool fiber is oval or elliptical, and includes three layers: (1) the medulla, which is the section in which the pigment or color is carried and which provides air space; (2) the cortex, which makes up most of the fiber and consists of microscopic cells that pack the area; (3) the outer layer consists of a fine network of small overlapping scales. The scale structure is responsible for the behavior of wool in felting and shrinkage [9]. Li and Hu reported a technique to pulverise the natural fires materials into nano-scale fibrious materials [10].

In this paper, we focus on the characterization of the morphology and functional properties of a cotton fabric treated by nano-scale wool fibrous materials.

2. Experimental

A multi-step wool fiber pulverization technology has been developed [10]: the first pulverization process (Millimetre scale pulverization) by using a rotary blade (Plant crusher, FZ102, Jielin, China); the second pulverization process (Microscale pulverization) by using an ultra-sonic crusher (JY99-II, Ningbo, China) and the third pulverization process (nano-scale pulverization) by using a nano-colliding machine (NT1500/5, Beijing, China).

The morphology of the wool fiber was examined by using scanning electron microscope (SEM) (JSM-6336F field emission scanning electron microscope, JEOL, Japan) and morphology of the powders obtained after the three steps pulverization was characterized by using a scanning probe microscopy (SPM) (CSPM2000, Beijing, China).

Further to characterize the superfine wool powders, the size distributions of the first, second, and third pulverised wool powders were analyzed by using a LS 13320 particle size analyzer (Beckman Coulter, CA, USA). In order to study whether there are any chemical changes of wool during the pulverization, the FTIR spectra of the pulverised wool powders at different stages were tested by using the KBr disc technique for sample preparation and testing with a Perkin-Elmer 2000 Fourier transform infrared spectroscopy (FTIR) (Wellesley, MA, USA).

To explore the functions of the nano-wool fibrous materials, a pure cotton woven fabric was treated with the emulsions prepared with nano-wool fibrous materials. The basic physical properties of the fabric are listed in Table 1. Before treatment, all the specimens were washed and dried following the method suggested in ISO 6330. A nano-wool emulsion was prepared by using pure water and dry nano-wool fibrous material. During the treatment, the specimen was dipped into a nano-wool fibrous solution for 10 min and then padded once with the emulsion. Finally, the specimen was dried and cured in an oven at 130 °C for 5 min.

Table 1
Basic physical properties of the cotton fabric used

Content	100% cotton
Structure	Plain
Weight (g/m^2)	190
Thickness (mm)	0.44
Color	White

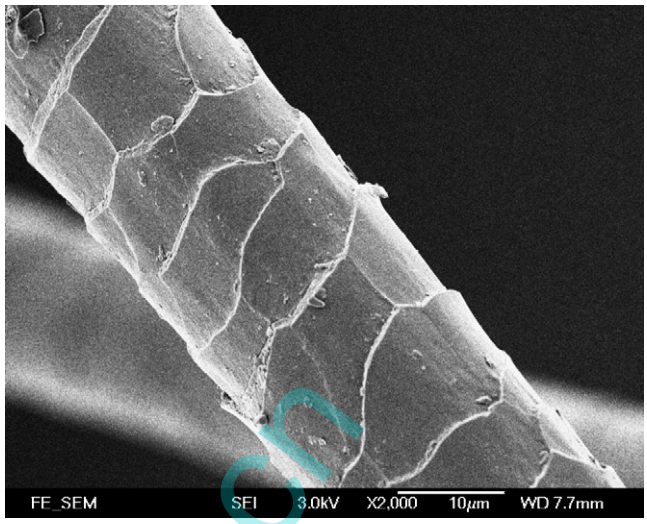


Fig. 1. SEM photo of a single wool fiber.

The thermal properties of the treated/untreated fabrics were evaluated using a KES-F7 Thermal Labo II (Precise and Prompt Thermal Prosperity Measurement Instrument, Japan), which can evaluate not only the warm/cool feeling (Q_{max} value), but also the thermal conductivity and insulation value (warmth retention ratio).

To determine the influence of the treatment on fabric water absorbency, Moisture management tester (MMT) was used to characterize the liquid transfer properties of the fabrics [12].

3. Results and discussions

Wool fibers used in this experimental were 60–120 mm in length and around 25 μm in diameter. A typical fiber SEM image is illustrated in Fig. 1.

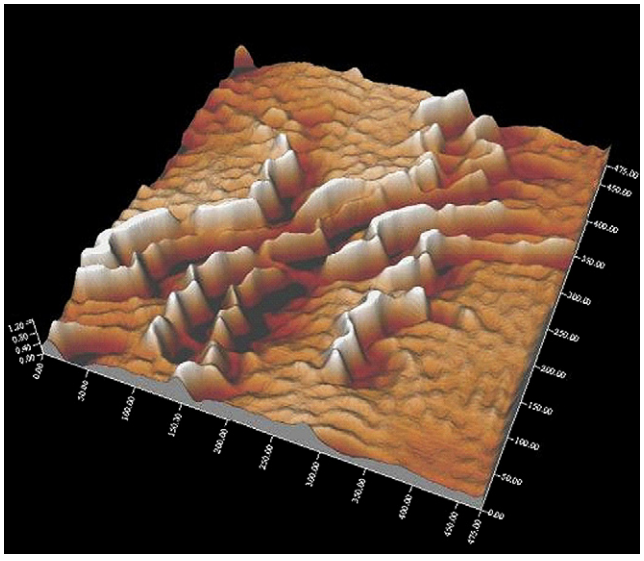


Fig. 2. SPM image for wool particle after the third step pulverization.

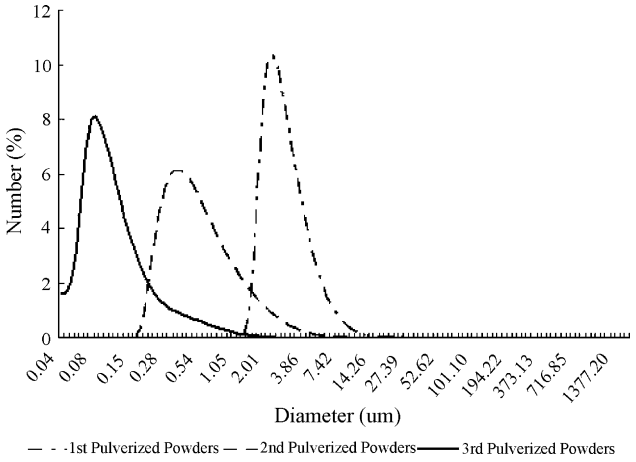


Fig. 3. Particle size distributions of the first, second and third pulverised wool particles.

3.1. Morphology of nano-wool fibrous materials

Fig. 2 shows a SPM image of wool particles after the third pulverization. AS shown in Fig. 2, the wool particles after the third pulverization have a fibrous shape with length of around 80–300 nm and diameter of 10–80 nm.

3.2. Particle size distribution

The results of particle size distribution analyses are shown in Fig. 3. The peak or mode diameter of the particles is around 3.5 μm after first pulverization, 0.5 μm after the second pulverization and 100 nm after the third pulverization. The difference in results between the SEM pictures and the particle size analysis may be attributed to a number of potential causes: (1) the powders in a specific area were randomly selected; (2) the particles were assumed to be spherical in the particle size analysis, while the actual wool particles are in fibrous form; (3) the particle size analysis was based on the counting of number percentage of the powder.

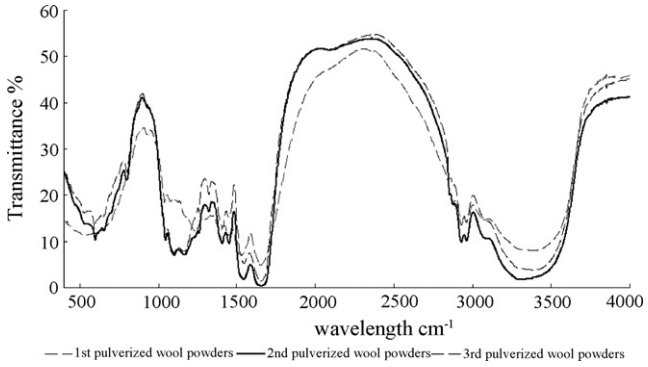


Fig. 4. FTIR absorption spectra of wool particles in the pulverization stages.

3.3. FTIR analysis

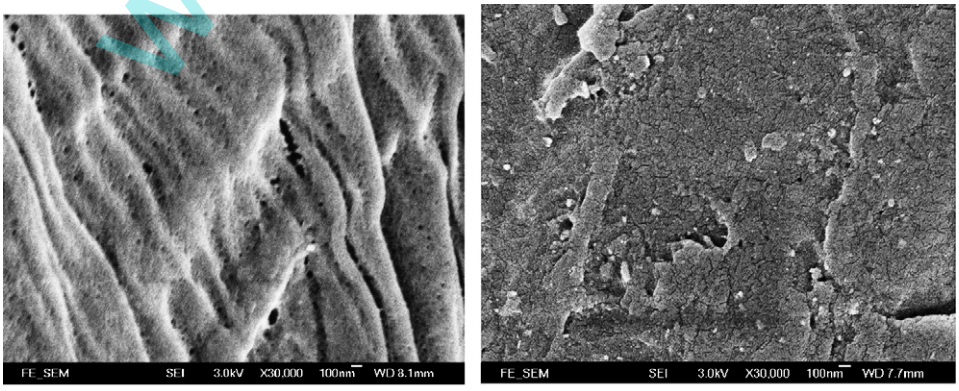
Fig. 4 shows the results of FTIR analysis. There are no significant changes in the chemical structure of wool particles after the pulverization processes. However, XRD results showed that the crystallinity percentage of wool powders decreased from 47.9% of the first pulverised wool powder to 12.1% and 5.4% of the second and third pulverised wool powders, respectively [11].

Fig. 5 shows the SEM images of cotton fiber surfaces before treatment and after treatment. Clearly, the fiber surface is covered a film of nano-wool fibrous material after treatment.

3.4. Warmth retention property

Fig. 6 shows the results of measurements of the thermal properties of the treated fabrics in comparison with the untreated fabrics. Comparing with untreated fabric, the thermal conductivity of cotton fabrics is decreased. These results indicate that thermal properties of treated fabric have been changed and the ability of thermal retention is increased.

Fig. 7 shows the Q_{max} values, which is an index to represent the ability of the fabrics to let us feel cool sensation when we touch the fabrics. The higher the Q_{max} value, the cooler feeling we have. It is clear that after treatment, the Q_{max} value decreased



(a) (b)

Fig. 5. Cotton fiber surface morphology before and after treatment with the nano-wool fibrous materials: (a) untreated cotton fiber surface and (b) treated cotton fiber surface.

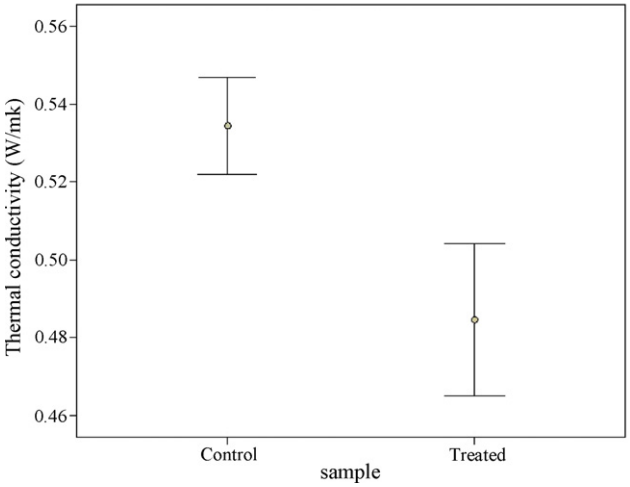


Fig. 6. Thermal conductivity properties of treated and untreated fabrics.

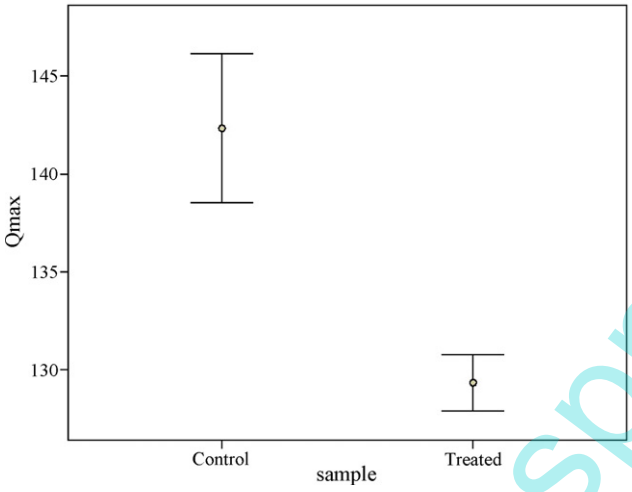


Fig. 7. Q_{max} values of treated and untreated fabric.

significantly, indicating that the treated fabric is warmer to the touch than the untreated fabric.

3.5. Liquid absorbency

Fig. 8 shows the results of fabric liquid moisture management properties. Comparing with untreated fabric specimens, the fabric maximum absorption rates on treated fabric decreased significantly. The maximum absorption rate at the fabric top surface is decreased from around 300 for untreated fabric to 20 after the treatment, suggesting that the nano-wool fibrous materials change the surface energy of cotton fibers and reduce their liquid absorbency capability.

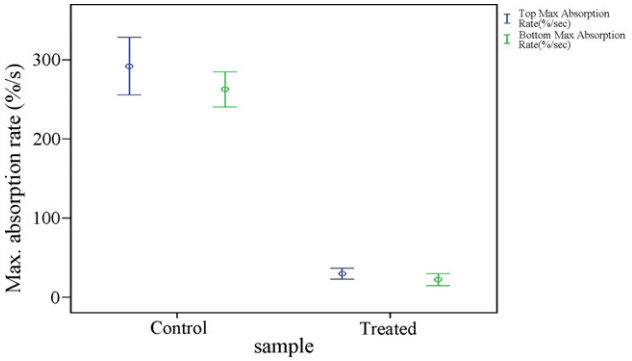


Fig. 8. Absorption rates on fabric both surfaces.

4. Conclusions

In this paper, the morphology and functional properties of nano-wool fibrous materials, which were obtained by using a patent pending technology to pulverise natural wool fibers into nano-scale particles, are investigated. Test results show that the prepared nano-wool particles are in fibrous shape with length of around 80–300 nm, diameter of 10–80 nm and have same chemical structure as wool fibers. The mode particle size was around 100 nm.

Nano-wool fibrous materials were treated on a pure cotton fabric. We found that nano-wool fibrous materials covered cotton fiber in the means of a film, which significantly reduce fabric surface water absorbency, thermal conductivity and Q_{max} values. These results indicate that the nano-wool fibrous materials can be used as a functional agent for functional finishing of cotton fabrics.

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