This is the published version:


Available from Deakin Research Online:

http://hdl.handle.net/10536/DRO/DU:30062887

Reproduced with the kind permission of the copyright owner

Copyright : 2013, Fibre Society
Enhancing Thermal Conductivity of Cotton Fabrics with Nanocomposite Coatings

Amir Abbas, Yin Zhao, Xueqiu Wang, Tong Lin
Australian Future Fibre Research and Innovation Centre, Institute for Frontier Materials, Deakin University,
Victoria 3216, Australia

tong.lin@deakin.edu.au

INTRODUCTION

Heat transfer is vital for many textiles including sportswear, work uniforms, shoes, bedding, and healthcare products. Such a process in porous materials is complex and often involves three main routes (conduction, convection, and radiation), with the heat conduction being more significant than the other two. Conventionally, heat transfer in fabrics is adjusted mainly through changing fabric thickness, areal density, porosity, or weave structure. Little attention has been paid to increasing the thermal conduction of fabrics through surface finishing with a thermally conductive material.

Carbon nanomaterials, such as carbon nanotubes (CNTs) and graphene, have been recently reported to have excellent thermal conductivity. The thermal conductivity of multi-wall carbon nanotubes (MWCNTs) has been measured to be as high as 3000 W/mK.1 Graphene, a single layer of graphite, was recently reported to have even higher thermal conductivity. At room temperature, the thermal conductivity of a single-layer graphene was reported to be 5300 W/mK.1 Boron nitride (BN) is another thermal conductive material widely used as filler for making thermo-conductive adhesives, pastes, and greases. Hexagonal boron nitride (h-BN) is similar to graphite having a planer structure, thus being soft and fibrous h-BN has a high in-plane thermal conductivity of 2000-6000 W/mK.2

Here we report the effects of the composite coatings containing three different fillers (MWCNT, graphene and BN) on the thermal transfer properties of cotton fabrics.

EXPERIMENTAL

The coating solutions were prepared by dispersing the fillers in a solution containing 4 wt% Hexcel E35 resin and 12 wt% 3:1 N,N-dimethylimidazolidinone-dimethylformamide, followed by sonication of the solution for 2 hours. After coating, the corresponding solid content of the fillers in the coating layer was controlled at 11.1, 20.3, 33.5 and 50.0 wt%.

The coating solutions were applied to the cotton fabric by a dip-paste-dry technique. Sample was first dipped in the coating solution and then passed through an Atlas wringer to remove the excessive solution. A 100% wet pick-up was set by adjusting the pressure on the side of the platten. The fabric was dried and then cured at 130°C for 10 minutes in a forced-air oven. Finally, the fabric was washed with hot and cold water separately to remove the unfixed chemicals.

For the measurement of thermal conductivity, a purpose-designed sample was employed, as illustrated in Fig. 1. A circular cylinder (100 mm diameter x 100 mm length) heat source was insulated on three sides to allow only one face to contact with fabric samples for heat transfer. A thermocouple probe with temperature measurement range of 40-150°C was fixed on the outer wall of the cylinder that was in contact with the fabric. During the test, the heat source was heated to 50°C and then left to cool down naturally. Thermal conductivity was calculated by using the Newton’s law of cooling.

![Fig. 1 Schematic illustration of the experimental setup.](image)

The IR camera (IRC thermo (tackle)) was also used to record the temperature change of the whole fabric surface. The recorded thermal images were processed with ImagePro Plus 4.0 software. For recording the heating process, IR thermography video was taken instantly after the fabric was brought in contact with the preheated cylinder at a preset temperature of 50°C. For a cooling process, the fabric was first heated for 10 minutes with the heat source (30°C), and the IR thermography video was recorded instantly when the source was removed off the fabric.

RESULTS AND DISCUSSION

After coating, the cotton fiber surface was covered with a uniform layer of resin containing nanofillers, which was verified by SEM (not shown here). With increasing the solid content of the fillers, the loading amount of the fillers on the fibers increased.

The thermal resistance and the thermal conductivity of the fabric samples are presented in Fig. 2. For the fillers coated with resin only without any nano fillers, the thermal conductivity was 0.047 ± 0.005 W/mK, which was 59% higher compared to the uncoated cotton fabric. When the coating layer contains 11.1 wt% fillers, the thermal conductivity was increased obviously. For graphene, BN and MWCNT, the thermal conductivity of the coated fabric changed to 0.078 ± 0.008, 0.074 ± 0.003
The equilibrium temperature of the coated fabrics during cooling was also measured (Fig. 4). During the test, all the coated samples were heated for 10 minutes so that the sample was heated to maximum equilibrium temperature, and then cooled naturally in a controlled ambient condition. After 2.5 minutes of cooling, the minimum temperature was measured. For the uncoated fabrics, the equilibrium temperature was 30.4 °C. The coated fabrics exhibited good cooling behavior and remained at lower equilibrium temperature than the control fabric. With increasing the filler content in the coating layer, the equilibrium cooling temperature decreased. The lowest equilibrium temperature was recorded to be 27.5 °C, which resulted from the 30.0 wt% graphene coating. However, for the BN and MWNT coating with the same content, the equilibrium temperature was 28.4 °C and 29.4 °C, respectively.

CONCLUSIONS

These thermally conductive nano fillers, graphene, MWNT, and BN, have been used to form composite coatings on cotton fabrics. Our study has indicated that they all increase the thermal conductivity of the fabric, and the graphene coated fabric showed the best improvement. BN composite coating was more effective than MWNT.

REFERENCES