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THE APPLICATION OF SILICA AND GLASS FIBERS IN EFFECTIVE THERMOINSULATION OF WINTER APPARELS

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Abstract

Silica fibers are inorganic soft fibers which can potentially be used for thermoinsulation of winter sportswear. Compared to polyster fibers, silica fibers reflect infrared light two times better. During winter time, this property is useful to maintain heat during sport exercise. At the same time, silica fibers are thin and straight, which aid to circulate air and transfer moisture through clothes. We have obtained non-woven composite containing 75% of silica fibers and 25% polyester fibers, with linear density 6 denier which is 20% warmer compared to one made of pure polyester fibers. At the same time, silica fibers allow fabrication of very thin layers of non-woven fabric with improved thermal protection. Moreover, samples of non-woven materials made with silica fibers possess very low stiffness properties – at the range of 1.5-2 newtons, this allows fashion design of comfortable winter sportswear.

1. Introduction

A number of requirements are applied to winter sportswear which is different from ordinary clothing. Sport winter clothing should have good breathability, provide sufficient warmth, and it is desirable to be thin and not stiff. This is essential so as not to hamper the athlete's movements [1].
The layer of thermoinsulation in winter clothes has important value. In the development of thermoinsulation for sports apparel, we have to take into account that the thermoinsulation should be more breathable than in casual clothes. It is known that the radiation component of heat loss can be up to 60% of the total heat dissipation from human body at sport exercises [2, 3]. Therefore, thermoinsulation for sportswear may cede to casual thermoinsulation on the convective component of heat transfer. Yet, it has to succeed in the radiation part of heat loss, meaning, reflecting heat back to the body of the athlete. Thermoinsulation should not block air movement, especially during intensive movements of athlete. Thus, it is theoretically possible to forgo the complex structure of the thermoinsulation to make it simpler.
Considering the whole set of requirements, it seems appropriate to use strait, hydrophobic, non-textured fibers with small diameters, possessing good infrared reflection property.
For the development of thermoinsulation which meets theoretical requirements, we have decided to use silica fibers with a variety of its content in non-woven materials, mixing them with synthetic polyester fibers. Silica fiber reflects light quite well, they are soft and do not absorbs moisture.

2. Experimental Work

Silica fibers with 9 um diameter and 10 cm cut length were purchased from Joint Stock Company "Polotsk-Steklovolokno". Bicomponent stapled polyethylene/polypropylene fibers with linear density 2 and 6 denier (PE/PP 6D and PE/PP 2D) and cut length 51 mm were purchased from Joo Sung Sea &Air Co., Ltd.

Samples of non-woven fabric have been prepared using laboratory Carding Machine (Mesdan). All samples have the same surface density - 100 g/m^2. Thermobonding of samples has been realized at 140°C during 5 min in fabric laboratory drier (Mesdan). Measurement of reflectance has been done by means of UV-Vis-NIR Agilent Technologies Spectrometer (Cary 5000 and DRA 2500) in the wave range 175-3300 nm. Measurement of thermoinsulation properties has been performed on Integrated Sweating Guarded Hotplate 8.2 from Thermetrics. Measurements have been done according to ASTM F1868. SM 6360 microscope with acceleration voltage 0.5-30 keV has been used to study fibers structure and surface. Stiffness of non-woven samples has been measured by means of Digital Pneumatic Stiffness tester (GT-C70B/GESTER).

3. Results and Discussion

We have discovered that silica fibers may play different roles in non-woven materials. The most promising composition of thermoinsulation samples were a mixture of silica fibers with thick polyester fibers, for example, fibers with linear density of 6 denier (figure 1).

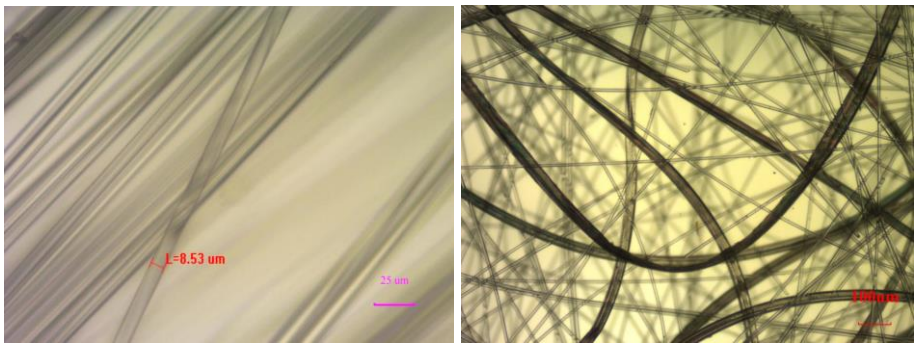

Figure 1. Silica fibers (left) and non-woven fabric: polyester 6 denier (25 wt%) and silica (75 wt %) fibers (right)

In such combination, thinner silica fibers occupy the space in non-woven fabric which is created and supported by thick fibers. In this case, thick fibers are responsible for mechanical properties, whereas thin silica fibers provide good thermoinsulation properties. Silica fibers are straight and smooth that provides good breathability and air exchange.
Silica fibers do not have big difference with polyester fibers by appearance and feel. In addition, silica fibers reflect visual and IR parts of spectra (figure 2) which should improve thermoinsulating property.

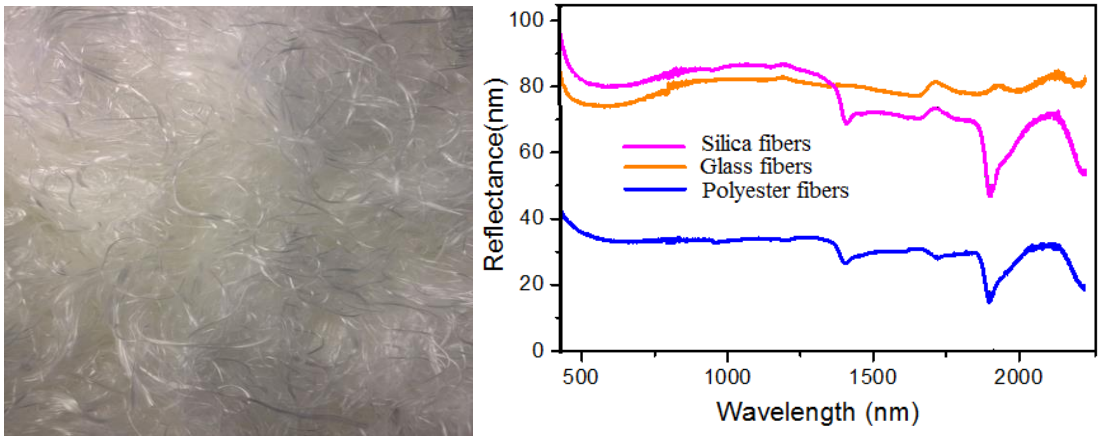

Figure 2. Silica fibers (left) and Reflectance property of silica, glass and polyester fibers (right)

Reflection capacity of silica fibers are comparable with that of glass fibers, and exceeds the reflection ability of polyester fibers by at least two times. This property is important for winter

apparel due to the speed of heating of thermoinsulation and reflection of heat which influence the customers' choice.

We have prepared two series of non-woven samples with different amount of silica fibers. One series has been prepared based on thick polyester fibers with linear density 6 denier; whereas the second series has been prepared based on thin 2 denier polyester fibers. Properties of different non-woven thermoinsulations fabric obtained with the addition of silica fibers are given in Table 1. We can see from Table 1 that there is an augmentation in thermoinsulating property by 24% for series with 6D fibers and by 20% for the series with 2D fibers if we increase the amount of silica fibers in non-woven composite. For composition with 6D fibers, we have a stable increase in CLO value when increasing the amount of silica fibers in the composite. However, for 2D fibers we have a maximum in CLO value for the composition which contains 25% of silica fibers. It is related mostly with the balance between two ways of heat lost: convection and irradiation. Comparing with non-woven fabric made of pure polyester fibers, addition of silica fibers provided a decrease of thickness of up to 3 times with the simultaneous improvement in thermoinsulation.

Table 1. Properties of non-woven thermoinsulation containing different amount of silica fibers.

Composition of non-woven material	Thickness, mm	Thermoinsulation, CLO (using Rct)	Stiffness, N
PE/PP 6D 100%	6.14	1.59	34.4
PE/PP 6D: Silica fibers 25:75	3.74	1.65	4.2
PE/PP 6D: Silica fibers 50:50	2.45	1.92	2.3
PE/PP 6D: Silica fibers 75:25	1.78	1.97	1.5
PE/PP 2D 100%	5.73	1.81	17.8
PE/PP 2D: Silica fibers 25:75	6.90	2.16	10.2
PE/PP 2D: Silica fibers 50:50	4.02	2.03	5.8
PE/PP 2D: Silica fibers 75:25	2.19	1.96	2.4

At the same time, we immediately see that silica fibers dramatically decrease stiffness of non-woven fabric from 34 to 1.5 newtons in the case of 6D polyester fibers. Decrease of thickness with simultaneous improvement of softness is a very useful property combination which is necessary for winter apparel.

4. Conclusions

We discovered that silica fibers can be used as an additive in fabrication of thermoinsulation for sport apparel. Addition of silica fibers to common polyester fibers provides an increment of thermoinsulation property by 20-25%. At the same time, silica fibers results in significant decrease in stiffness of non-woven fabric prepared by thermobonding. Additionally, very thin non-woven material can be prepared based on silica fibers, which could be used for winter sport apparel where bulkiness is not desirable property.

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