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EFFECTS OF GINNING AND CARDING ON TENSILE AND MORPHOLOGICAL PROPERTIES OF COTTON AFTER REPEATED WASHING AND DRYING

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Abstract

The ginning and carding processes are designed to enhance fiber uniformity and degree of orientation in addition to removing trashes and foreign matters for the production of yarn. However, these processes also damage the fibers during the processing and lower the quality of the fibers. In addition these negative effects of processing conditions may be reflected by the morphological characteristics of fibers unraveled from yarns in T-shirts produced by the conditions.

While the qualities of the resulting yarns, fabrics, and garments are adversely affected by various processing conditions, the extent of the damage, in regard to the fiber properties, has not been well quantified by scientific means. This research was designed to elucidate the effects of ginning and carding processes on the fiber quality by applying two ginning rates, two lint cleaner systems, and two carding rates.

T-shirts produced by various processing conditions were washed and dried for 32 cycles by a commercial washer/dryer. The dimensional properties were measured and three T-shirts having different amount of shrinkage were picked. Tensile and morphological properties of fibers in selected T-shirts were measured and analyzed statistically. The T-shirt produced with cotton undergone high ginning rate, 2 lint cleaners, and high carding rate showed the least amount of shrinkage during repeated washing/drying. However, this T-shirt showed the lowest average values of breaking strength and breaking elongation of fibers. We could see that the number of lint cleaners had negative effect of fiber tensile properties. Fiber tensile properties from card slivers corresponding to the selected three T-shirts did not show definite effects of any processing variables considered. However, from card sliver to T-shirt, fiber tensile properties were decreased significantly. Especially, the decrease of the mean and the variance of the breaking elongation were quite noticeable.

The differences in the surface characteristics of fibers from T-shirts undergone repeated washing/drying were also seen by the scanning electron microscope. Fibers undergone high ginning rate, 2 lint cleaners, and high carding rate had more loose fibrils on fibers and more loose fibers on fabric surfaces.

Introduction

Although studies were made extensively on tensile properties of cotton fibers in bundle forms in the past, little research has been conducted as single fibers. It is natural to expect that the changes in the mechanical properties of cotton fibers brought about by the machine actions during the manufacturing processes would exert indelible effects on the characteristics of the resulting fabrics and garments. However, the modes and extents of machine actions or damages inflicted upon the cotton fiber during ginning and the subsequent processes are too numerous and complex, and often indeterminate, to be amenable to be quantified or identified. Investigations on this important issue was not possible simply due to lack of means for testing the tensile properties of a sufficiently large number of cotton fibers before and after each stage of processing. Yet, it is readily conceivable that the rapid and repeated loading of cotton fibers may leave irreversible effects on cotton fibers.

Loss of the fiber's "liveliness" for instance, through impairment of its elasticity, may be reflected in terms of certain latent changes in the stress-strain behavior of fibers, yarns and fabrics. More importantly, how these changes are manifested during the lifetime of a product is of great interest and significance.

As a part of larger research, we investigated the effects of ginning and carding on cotton fibers in T-shirts undergone repeated washing/drying.

Materials and Methods

Ginning and Carding Conditions

Stoneville (STV) 747 cotton variety was selected. These cottons were processed through 8 different processing conditions; two levels of ginning rates (75% and 125% of normal ginning rate), two lint-cleaning methods (1 lint-cleaner and 2 lint cleaners), and two levels of carding rates (60 lbs./hr and 120 lbs./hr).

Spinning, Knitting, and T-shirt Manufacturing

Each group of cottons was processed to produce 20/1 Ne ring spun yarns with Sinzer 321 Ring-spinning machine with a spindle speed of 14,000 rpm. The 1×1 fabrics were knitted for manufacturing T-shirt garments. After scouring and finishing, T-shirts were manufactured with the fabrics.

Repeated Washing/Drying

After length and width measurements, T-shirts undergone various ginning and carding conditions were washed and dried 32 cycles in commercial washer/dryer. After repeated washing/drying, the length and the width of the T-shirts were measured in order to record the amount of shrinkage during washing/drying.

MANTIS® Single Fiber Test

A total of 11,600 single fiber tensile tests were performed on cotton fibers sampled from card slivers and T-shirts. Over 1600 (maximum 2000) tests were performed on each sample. MANTIS® single fiber tester tested the fibers and tensile property data were analyzed statistically by SAS® statistical package. For a preliminary research, 1200 tests were performed for fibers from the unwashed T-shirt, which showed the highest amount of shrinkage.

Results

Shrinkage Properties of Washed T-Shirts

Lengths and widths of T-shirt were measured at the end of every 4 W/D cycles in this repeated washing/drying experiment. The measurements were taken before washing, and after drying**.** After 32 washing/drying cycles, we have analyzed the shrinkage data and selected three T-shirts out of eight T-shirts with various processing conditions; ones with the highest amount of shrinkages, the lowest one, and the one in between. Figure 1 shows the length shrinkage of the three T-shirts. The T-shirt with the highest amount of shrinkage was made of fibers undergone high ginning rate, 1 lint cleaner, and high carding rate. The relationships between the amount of shrinkage and the processing conditions are shown in Table 1. The T-shirt with the lowest amount of shrinkage was made of fibers undergone high ginning rate, 2 lint cleaners, and high carding rate. From the above results, it may be possible to say that the number of lint cleaner had positive effect on the dimensional stability of T-shirts. We studied the tensile and morphological properties of fibers from the three T-shirts.

Fiber Tensile Properties from Washed T-Shirts

As a first step of the research, we selected a T-shirt with the highest amount of shrinkage. We selected an unwashed T-shirt and card sliver corresponding to the T-shirt as references. Fibers from the washed T-shirt, the unwashed T-shirt, and the card sliver were tested by MANTIS® single fiber tester. Table 2 shows the summary statistics of the average breaking strength and breaking elongation for the card sliver, unwashed T-shirt, and washed T-shirt showing the highest shrinkage. Both the breaking strength and the breaking elongation were decreased from carding process to repeated washing/drying significantly. During the repeated washing/drying cycles, however, the changes of the tensile properties were not noticeable. Although the breaking strength decreased significantly, the breaking elongation did not decrease during repeated washing/drying. Therefore, we could conclude that the decrease in breaking elongation is not due to washing/drying, but spinning and knitting.

Three washed T-shirts with different amount of shrinkage were studied in regard to fiber tensile properties. Table 3 shows summary statistics of the tensile properties for three T-shirts with different amount of shrinkages. By the statistical analyses, there were significant differences in both the breaking strength and the breaking elongation between Low Shrinkage T-Shirt and High Shrinkage T-Shirt, while no differences between Medium Shrinkage T-Shirt and High Shrinkage T-Shirt. In other words, T-shirts of fibers undergone high ginning rate, 2 lint cleaners, and high carding rate showed the lowest values of the tensile properties.

Fiber Tensile Properties from Card Slivers

We have observed that the tensile properties of the fibers taken from the three T-shirts showed differences after laundering and drying. As a reference test, fiber tensile properties of card slivers corresponding to three T-shirts were compared. There was a significant difference in the breaking strength between Low Shrinkage T-Shirt and High Shrinkage T-Shirt while no differences in the breaking elongation were found for the two T-shirts. On the contrary, there were differences in the breaking elongation and no differences in breaking strength between Medium Shrinkage T-Shirt and High Shrinkage T-shirt. Therefore, we could not draw a generalized conclusion about the relationship between tensile properties and the processing conditions for the fibers from card slivers.

When closely investigated, however, we could find that using of one lint cleaner would result in higher tensile properties than using of two lint cleaners regardless of carding rates. That means that the effect of lint cleaner was superior to the effect of carding rate.

Comparison of the Fiber Tensile Properties: Card Sliver vs. Washed T-Shirts

Regardless of the amount of shrinkage in the T-shirt, there were the effects of post-carding and laundering on the tensile properties of the fibers. The average values of the tensile properties from card slivers were greater than that of the T-shirts and the results were significant at 5 % error level. In addition, there were also significant changes in the distributional features of the tensile properties. Although both the breaking strength and breaking elongation of the fibers were seemingly altered during the processes, the distribution of the breaking elongation was changed much more; the mean breaking elongations and their standard deviations had decreased considerably.

From the above results, we could conclude that both the breaking strengths and breaking elongations of fibers were adversely affected by the post-carding processes and laundering steps. Especially the changes of the breaking elongation were quite noticeable. The fibers would be so stretched that they loose their elasticity during post-carding processes and washing/drying steps. Breaking strength of fibers, even though they are decreased after repeated washing/drying, was not affected as breaking elongation since the fibers were not broken during the processes. Therefore, we could consider the breaking elongation of fibers as a critical factor for assessing the fabric quality.

Morphological Properties of Fibers from Washed T-Shirts

Surface properties of cotton play a very important role in textile products and processes. In addition to contributing to yarn uniformity and mill efficiency, surface characteristics influence dye absorbency and reactivity rate as well as fabric feel, or handle. Quite possibly, it may also influence the shrinkage and tensile properties.

For these reasons, we planned to observe surface of cotton to elucidate the effects of process conditions on the surface properties of the fibers. We employed more advanced microscopic technique for more detailed observation.

Apparatus

Hitachi S-3200 variable pressure scanning electron microscope (ESEM) was used for the experiment.

Materials

Samples were cut in sizes of 0.5×0.5 mm from the three T-shirts and placed on the mount and coated with gold by the sputter coater.

Results

Figures 2 – 5 show the surfaces of fibers taken from the T-shirt with low shrinkage. The fabric surface with low magnification is shown in Figure 2. As we have already seen in the light microscopy test performed during the last period, the T-shirt with low shrinkage had more spaces between yarns than the T-shirt with high shrinkage. We can observe that the loose fibers on the fabric surface are widely scattered. When closely observed, fibers had many fibrillar fragments on their surfaces. The amount of fragments was shown to have decreased when the T-shirt with medium shrinkage was observed (Figures 6 – 9). Figures 10 – 15 show the morphology of the fibers from the T-shirt with high shrinkage. The T-shirt fabric with high shrinkage has shown almost no fibrillar fragments on the surface of the fibers. In addition, the loose fibers from the yarn were not so widely scattered instead of being entangle with peelings on the fabric surface.

Since high shrinkage T-shirt was undergone 1 lint cleaner and low shrinkage T-shirt 2 lint cleaners, we could expect that more lint cleaners has certain effect on causing fibrillar structure on fiber surfaces and loose fibers on fabric surfaces. We can conclude the multiple use of lint cleaners seems to weaken the fibers so that the fibers would be damaged more easily during repeated W/D.

Summary and Conclusions

For selected T-shirts of STV 747 cottons, the amount of shrinkage of T-shirts after repeated washing/drying depends on some processing conditions; the T-shirt of fibers undergone high ginning rate, 2 lint cleaners, and high carding rate showed the least amount of shrinkage, while the T-shirt of fibers undergone high ginning rate, 1 lint cleaner, and high carding rate showed the highest amount of shrinkage. Therefore, we could conclude the number of lint cleaner has adverse effect on the amount of shrinkage during repeated washing/drying. However, we could not assume the shrinkage during washing/drying as the total shrinkage occurred on fabric from fabric finishing process to washing/drying. With this reason, it will be inevitable to study the shrinkage during fabric finishing and scouring in order to investigate the relationships between processing condition and the shrinkage properties.

The tensile properties of fibers from highly shrunk T-shirt were studied as a preliminary research. Both the breaking strength and the breaking elongation decreased significantly from card sliver to unwashed T-shirt. However, only the breaking strength decreased during repeated washing/drying. We could conclude the breaking strength of fiber was affected adversely by heat and water during washing/drying.

Three T-shirts with various amount of shrinkage were studied. Fibers undergone two lint cleaners in ginning process showed low value of both the breaking strength and the breaking elongation while fibers undergone one lint cleaner showed higher values. This trend was seen in case of fibers from card slivers corresponding to the three T-shirts. In the comparison of T-shirt and corresponding card sliver, we found out that the average and the variance of the breaking elongation decreased significantly during post-carding processes.

Fibers from T-shirts undergone repeated washing/drying were observed by scanning electron microscope for studying morphological characteristics. Low Shrinkage T-Shirt in which fibers underwent high ginning rate, 2 lint cleaners, and high carding rate had large number of loose fibers on the fabric surface, and loose fibrils on the fiber surfaces. From the result we could expect that processing variables may result in damaged structures of fibers or fabrics.

Table 1. The relationships between process conditions and the three T-shirts with various amount of shrinkage.

T-Shirt Shrinkage	Ginning Rate	No. of Lint Cleaners	Carding Rate	Description
High	High	1	High	S-212
Medium	High	2	Low	S-221
Low	High	2	High	S-222

Table 2. Summary statistics of fiber tensile properties from card sliver, now-washed T-shirt, and washed T-shirt (high shrinkage T-shirt).

Sample Group	No. of Test	Variable	Mean	Std. Dev.	Minimum	Maximum
Card Sliver	3200	BS (gf)	6.644	2. 592	0.45	36.95
		BE (%)	20.501	8.216	-0.45	52.12
Non-washed T-shirt	1200	BS (gf)	5.848	1.956	0.47	16.51
		BE (%)	13.267	5.552	0.19	38.96
Washed T-shirt	1600	BS (gf)	5.641	2.012	0.49	14.26
		BE (%)	13.340	5.560	-0.41	46.48

Table 3. Summary statistics of fiber tensile properties from T-shirts.

Description	No. of Test	Variable	Mean	Std. Dev.	Minimum	Maximum
S-222	2000	BS (gf)	5.829	1.996	0.48	13.79
		BE (%)	12.775	4.944	-0.19	31.99
S-221	2000	BS (gf)	5.933	2.012	0.48	15.19
		BE (%)	13.389	5.032	0.17	37.12
S-212	2000	BS (gf)	6.015	2.036	0.49	16.99
		BE (%)	13.180	5.382	0.16	43.26

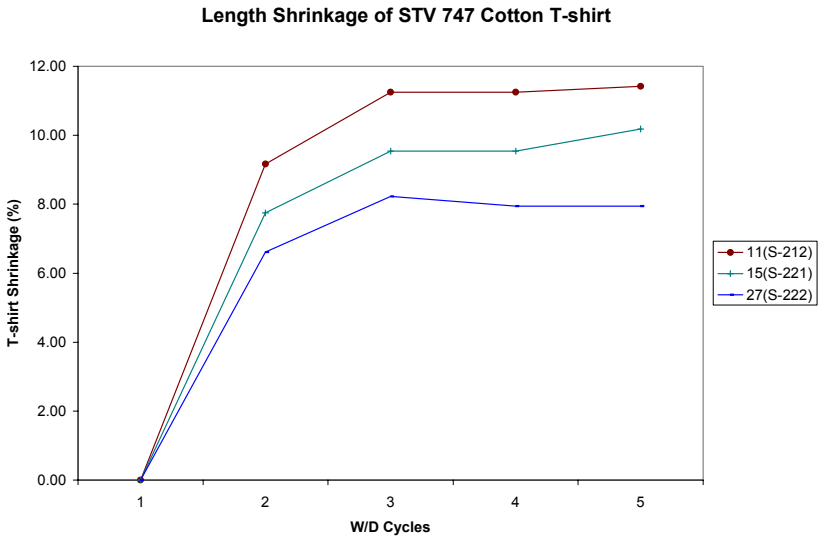

Figure 1. Length shrinkage (%) after 32 W/D cycles for STV 747 T-shirts.

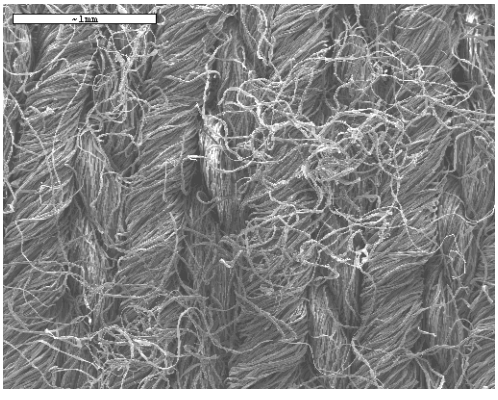

Figure 2. The surface of the T-shirt with low shrinkage.

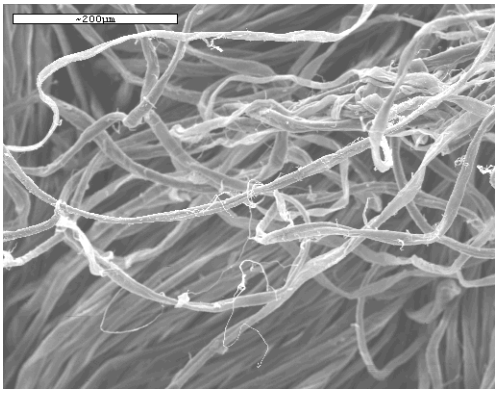

Figure 3. The fibers on the surface of the T-shirt with low shrinkage.

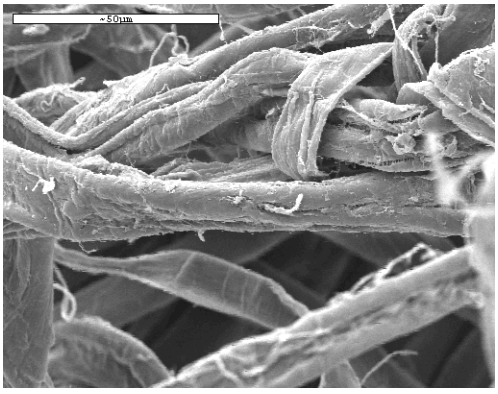

Figure 4. The fibers on the surface of the T-shirt with low shrinkage

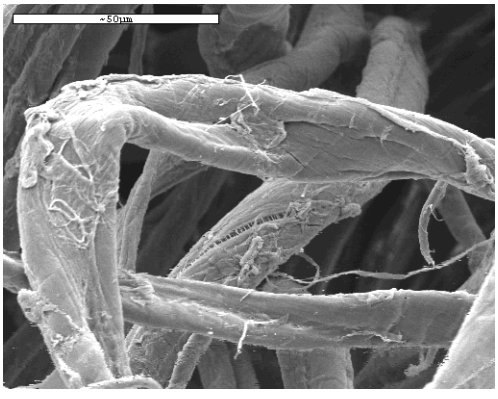

Figure 5. The fibers on the surface of the T-shirt with low shrinkage

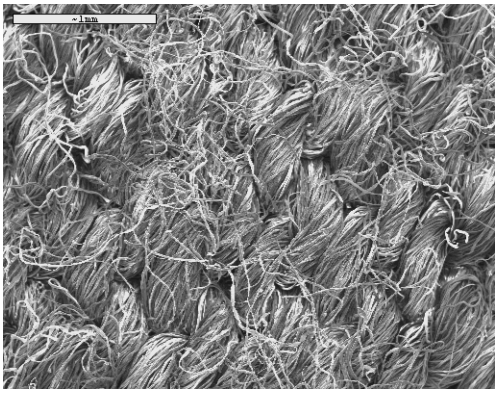

Figure 6. The surface of the T-shirt with mediocre shrinkage

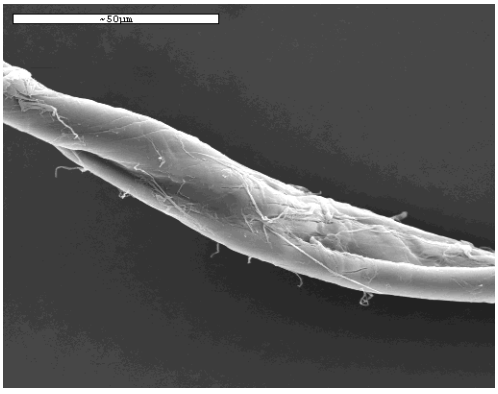

Figure 7. The fibers on the surface of the T-shirt with mediocre shrinkage

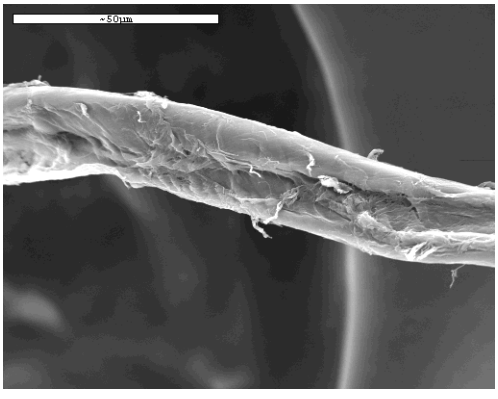

Figure 8. The fiber on the surface of the T-shirt with mediocre shrinkage

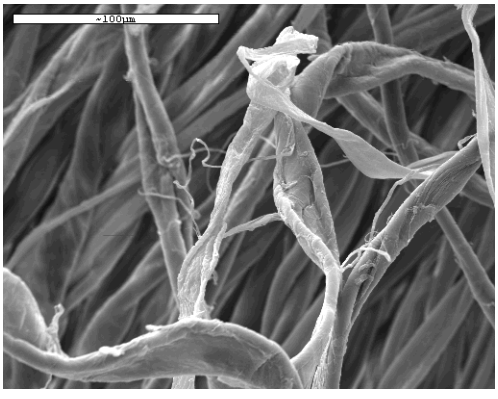

Figure 9. The fibers on the surface of the T-shirt with mediocre shrinkage

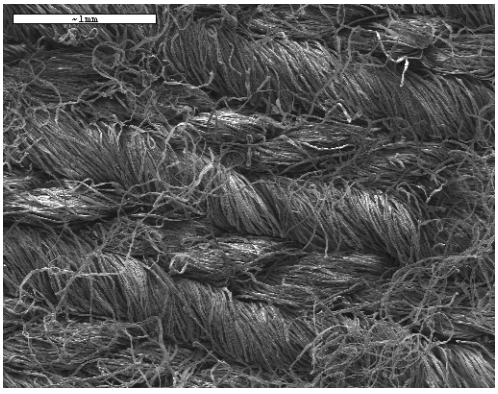

Figure 10. The surface of the T-shirt with high shrinkage

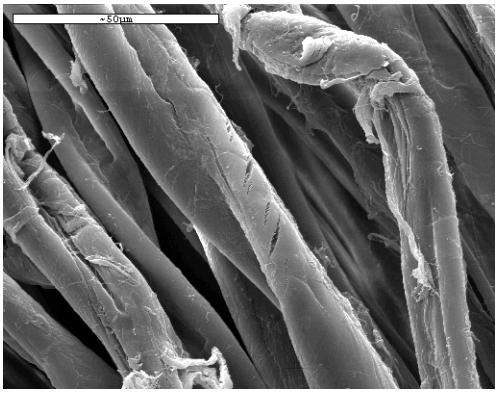

Figure 11. The fibers on the surface of the T-shirt with high shrinkage

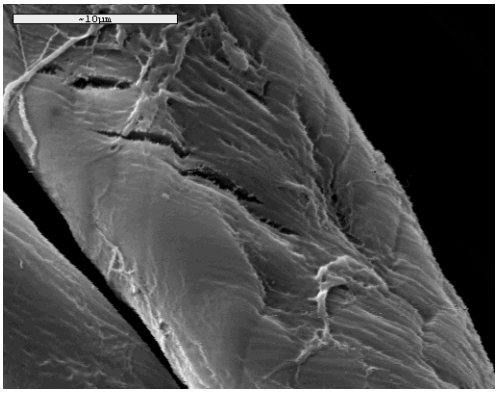

Figure 12. The fibers on the surface of the T-shirt with high shrinkage

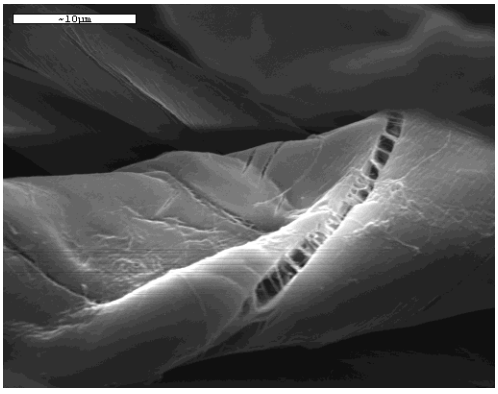

Figure 13. The fibers on the surface of the T-shirt with high shrinkage

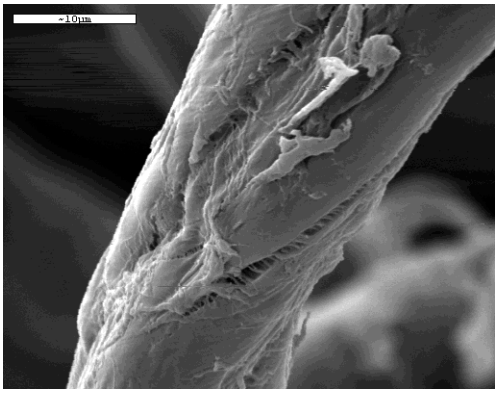

Figure 14. The fiber on the surface of the T-shirt with high shrinkage

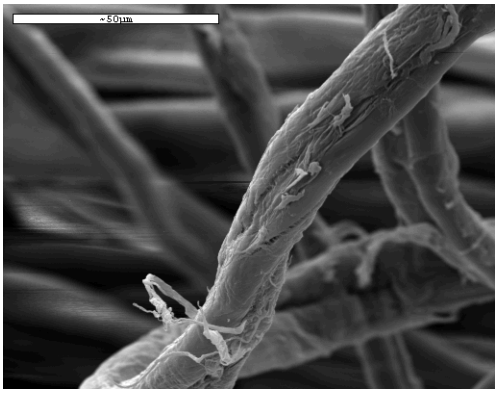

Figure 15. The fibers on the surface of the T-shirt with high shrinkage