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Preparation of antibacterial microfibre

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Three different kinds of antibacterial microfibres (270D, 300D and 330D) have been developed by adding 2-4 wt % nano silver masterbatch in the melt spinning process. The mechanical properties, silver content and morphology have been examined with tensile tester, inductively coupled plasma-optical emission spectrometer and scanning electron microscope respectively. Their antibacterial abilities are also studied with KS K 0693:2011. The results show that the added nano-particles have little influence on mechanical properties of antibacterial microfibres and their max strain and tenacity are similar to that of common manmade fibre. The fineness of the 270D, 300D and 330D samples are found to be 0.23, 0.26 and 0.30 den, and the corresponding added silver contents are 265.5, 231 and 259 ppm respectively. It is also observed that all samples bacteriostatic reduction rates are about 99.9% for both *Staphylococcus aureus* and *Klebsiella pneumonia* before washing. But after washing, it drops to 65.4%/75%, 91.9%/97.7% and 94.8%/99.9% respectively for both the bacteria in case of 270D, 300D and 330D samples. It is concluded that 300D and 330D microfibre samples have good antibacterial ability before and after washing.

Keywords: Antibacterial microfibre, Bacteriostatic reduction rate, Nano silver, Melt spinning

1 Introduction

Microfibre is a kind of synthetic fibre finer than one denier. The most common types of microfibres are made from a conjugation of polyester and polyamide[1]. Its products are environmental friendly cleaning textiles, which make a perfect cleaning without or with only a little detergent[2-4]. It was first developed by Dr. Miyoshi Okamoto during the 1960s, and then first publicized in 1990s in Sweden as a successful product. Starfiber was the first microfibre launched in the US market in early 1990s[5]. Since then, the market importance of microfibre has been rising throughout the world, and functional microfibre even makes it more outstanding.

Microfibre can trap the dust or greasy dirt inside of its special groove structure. However, if washed improperly, bacteria can grow on it after a long usage time, similar to other cleaning products. Under this context, successful antibacterial microfibre products are eagerly demanded in the market. Recently, the application of nano silver particles has been extended in a new approach to become antimicrobial agents[6-8]. The antibacterial effect of nano silver has been attributed to its small size and large surface area, which allows them to interact closely with bacteria and is not merely due to the release of metal ions in solution[9]. There are many kinds of antibacterial microfibres in the market. Most of them are antibacterial finishing products. However, few studies have been reported about the preparation of antibacterial microfibre through melting spinning. In this study, an innovative kind of antibacterial microfibre has been developed by adding nano silver particles in the spinning process.

2 Materials and Methods

2.1 Preparation of Antibacterial Microfibre

The polyester (PET) (SB500: Yizheng Yangtze River Chemical Fibre Corporation Co., LTD) and polyamide (PA) (BL2280H: Baling Petrochemical Corp) chips with nano silver were dried at 100°C and then the chips were melted and passed through separate channels. Nano silver masterbatch was added in both PET and PA chips; the addition rate was 2-4 wt %. The two flowing components would be blended together using an orange-disc-typed spinneret orifice under the control of flow meter[10]. After winding, the PET/PA (80/20) antibacterial microfibre was produced. Three different sizes of antibacterial microfibre samples, viz 270D, 300D and 330D were produced.

2.2 Mechanical Properties

Tenacity and maximum strain of polyester fibres, nylon 6 fibres and prepared antibacterial microfibres

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were investigated by tensile tester Instron 4411 according to ASTM D2256. Measurements of each fibre were repeated ten times under the same testing condition so as to obtain reliable average resulting data.

2.3 Chemical Element

Silver content of antibacterial microfibres was determined by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). Prior to the measurement, the samples were prepared by the method of acid digestion (detection limit 1mg/kg).

2.4 Surface Characterizations

The side view, cross section and fineness of the antibacterial microfibres were analyzed by scanning electron microscope (SEM).

Table 1—Physical properties of different kinds of fibres

Sample	Fineness den	Max strain %	Tenacity cN/tex
270D	0.23	24.2	30.8
300D	0.26	23.7	36.1
330D	0.30	22.4	26.7
Polyester fibre	2.08	18.3	31.9
Polyamide fibre	2.92	34.0	41.8

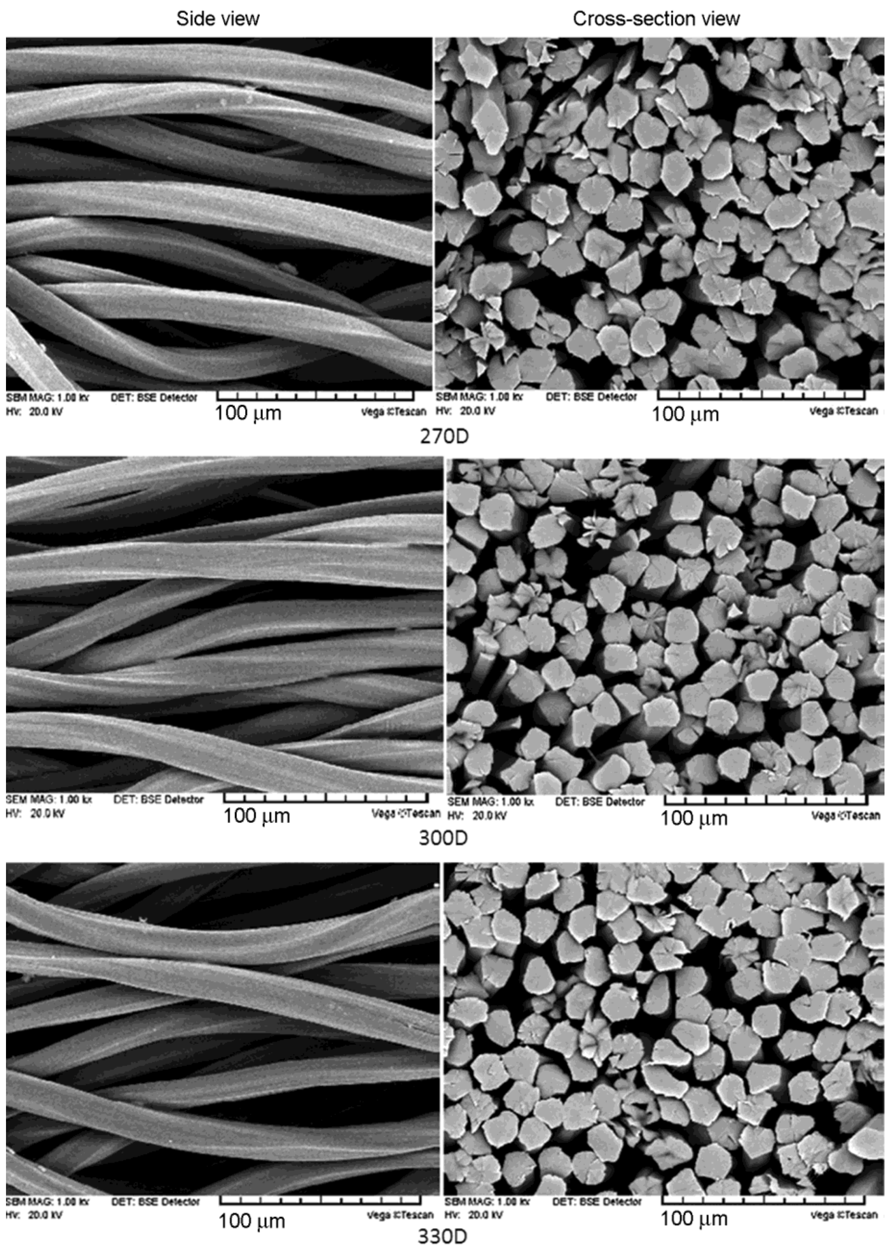


Fig. 1—Side view and cross-section of the prepared microfiber sample

2.5 Antibacterial Testing

Antibacterial property of the microfibre samples was tested using the standard (KS K 0693:2011)- Antibacterial activity of textiles. Colony forming units (CFU) and bacteriostatic reduction rate were calculated. The antibacterial ability of the washed microfibres was also measured. The samples were washed twenty times according to AATCC 150-2010.

3 Results and Discussion

3.1 Physical Properties

As demonstrated in Table 1, polyamide, polyester and antibacterial microfibres show similar characteristics in max strain and tenacity. This suggests that the added nano silver has little influence on the mechanical properties of antibacterial microfibres. In addition, the reason of similar physical properties of samples can be ascribed to the fact that microfiber, polyester and polyamide fibres are prepared from the same raw materials and melt spinning process. The fineness differences of the fibres were also listed clearly. As illustrated in Table 1, microfibres are found much thinner than polyester and polyamide fibres.

3.2 SEM Images of Microfibres

The side view and cross-section of the antibacterial microfibres images are shown in Fig. 1. In these images, part of the microfibres is split, caused by the mechanical stress during spinning. The size of the fibres is homogeneous, indicating that this kind of antibacterial microfibre has good spinnability. Furthermore, only a few silver particles are observed on the surface of the microfibres and most of them are inside the fibre[11]. In this case, the antibacterial microfibres have a good anti-washing ability, as proved in the washing test in the following part. Thus, the microfibres have long-lasting antibacterial ability and the silver particles can be continually released from the fibre in use[12].

3.3 Antibacterial Properties

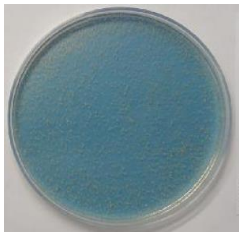
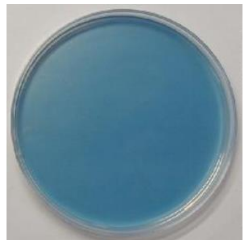
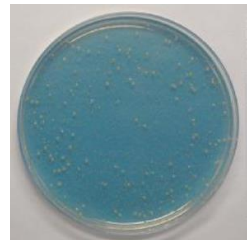
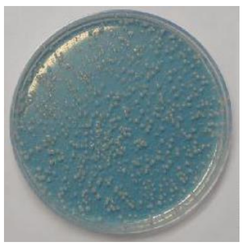
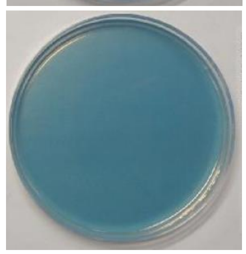
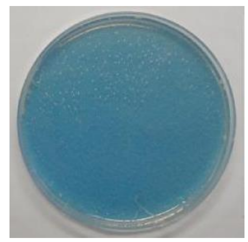
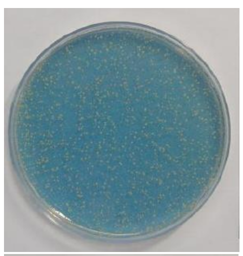
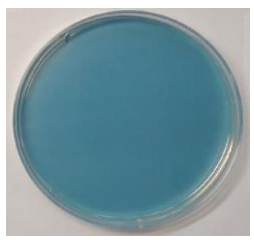
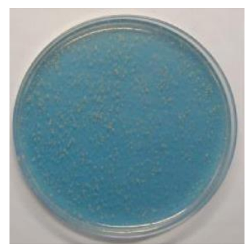
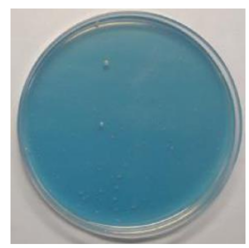
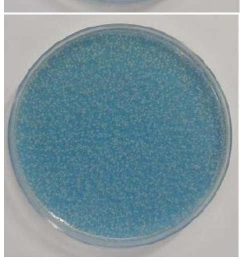
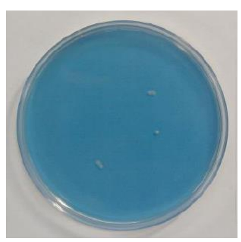
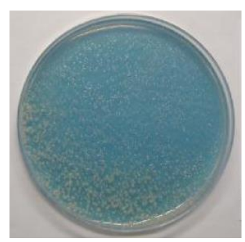
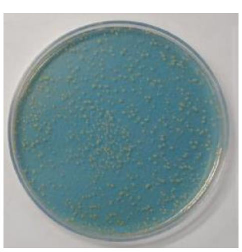
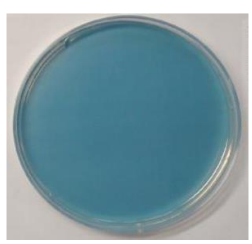
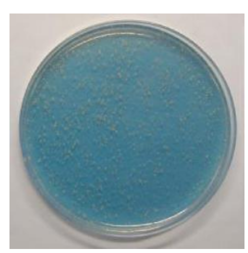
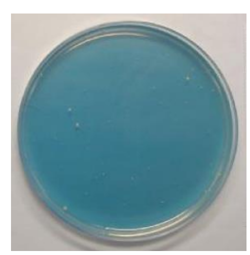
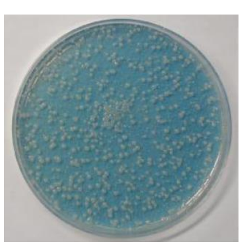
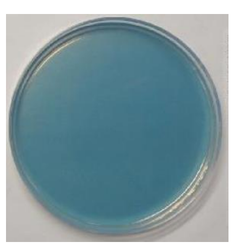
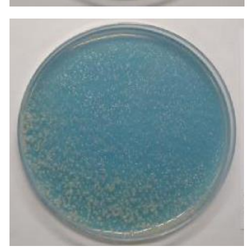
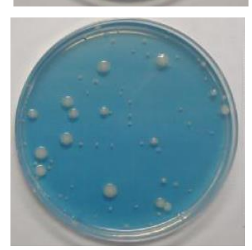
The silver contents of the microfibres are found 265.5, 231.0 and 259.0 mg/kg before washing and 136.4, 171.3 and 203.6 mg/kg after washing for 270D, 300D and 330D samples respectively. It is observed that the silver contents of all the samples decrease after washing, and the 270D sample has the largest silver loss. The difference in silver contents of the

Table 2—Antibacterial properties of microfibre samples

Sample[a]	Stages	Unwashed microfibres		Washed microfibres	
		Blank	Microfibres	Blank	Microfibres
270D					
Bacteria-1	At beginning	2.5×10^4	2.5×10^4	2.0×10^4	2.0×10^4
	After 18 h	5.7×10^4	<10	2.6×10^6	9.0×10^5
	Reduction rate	-	99.9	-	65.4
Bacteria-2	At beginning	2.3×10^4	2.3×10^4	2.2×10^4	2.2×10^4
	After 18 h	3.9×10^7	<10	4.0×10^7	1.0×10^7
	Reduction rate	-	99.9	-	75.0
300D					
Bacteria-1	At beginning	2.1×10^4	2.1×10^4	2.0×10^4	2.0×10^4
	After 18 h	2.8×10^6	<10	3.1×10^6	2.5×10^5
	Reduction rate	-	99.9	-	91.9
Bacteria-2	At beginning	2.1×10^4	2.1×10^4	2.4×10^4	2.4×10^4
	After 18 h	3.8×10^7	1.0×10^5	5.7×10^7	1.3×10^6
	Reduction rate	-	99.7	-	97.7
330D					
Bacteria-1	At beginning	1.9×10^4	1.9×10^4	2.0×10^4	2.0×10^4
	After 18 h	2.0×10^6	<10	3.1×10^6	1.6×10^6
	Reduction rate	-	99.9	-	94.8
Bacteria-2	At beginning	2.1×10^4	2.1×10^4	2.4×10^4	2.4×10^4
	After 18 h	4.8×10^7	<10	5.7×10^7	2.2×10^4
	Reduction rate	-	99.9	-	99.9

[a]Standard fabric: Cotton; Bacteria-1— *Staphylococcus aureus* ATCC 6538; Bacteria-2— *Klebsiella pneumoniae* ATCC 4352.

Table 3—Antibacterial testing images

	Unwashed microfibres		Washed microfibres	
	Blank	Microfibres	Blank	Microfibres
		270D		
Bacteria-1				
Bacteria-2				
		300D		
Bacteria-1				
Bacteria-2				
		330D		
Bacteria-1				
Bacteria-2				

three samples before washing can be caused by the uneven blending of the nano silver masterbatch. In addition, the samples antibacterial properties are also analysed (Tables 2 and 3). Tables 2 and 3 show the antibacterial testing results of the microfibres. It is easy to sum up that the three prepared microfibre samples possess good antibacterial ability of 99% reduction rate before washing. On the other hand, the antibacterial ability of microfibres decreases after washing twenty times. Compared to the other samples, the 270D sample shows an obvious decrease in antibacterial ability and its reduction rate falls to 65-75%. It can be ascribed to the smaller fineness and larger surface area of 270D microfibre in comparison to the other microfibres. However, the results show that the antibacterial microfibre samples have good anti-washing ability because the silver particles cannot be washed out easily, this endows the sample sustainable antibacterial ability[13]. Besides, the silver particles are more easily to be released out in washing. Moreover, it is noticed that the samples have much better reduction rate on *Klebsiella pneumoniae* than on *Staphylococcus aureus*. This suggests that silver has different biological activity to various bacteria.

4 Conclusion

The tenacity and max strain of the newly prepared microfibres are found to be similar to other manmade fibres. The fineness of the fibres is found much less than one denier, which comes in the microfibre range. In addition, most of the silver particles are found inside the fibres and the antibacterial microfibres show good spinnability, which is the key point for future mass production. All the samples have a good antibacterial function; more than 99% bacteriostatic reduction rate is obtained before washing. After washing, the bacteriostatic reduction rate of 270D, 300D and 330D samples are found to be 65.4%/75%, 91.9%/97.7% and 94.8%/99.9% for the two different bacteria respectively. Although further research about antibacterial microfibre fabrics is necessary. This study has provided a useful guide to the future industry production and shows a promising potential for the functional microfibre market.

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