

Antibacterial Efficacy of Nano Silver Finished Fabric on *Staphylococcus aureus* and Preliminary Test on Its Safety

Pranee Rattanawaleedirojn*, Kanokwan Saengkiattiyut
and Supin Sangsuk

*Metallurgy and Materials Science Research Institute, Chulalongkorn University,
Bangkok 10330, Thailand*

*Corresponding author. E-mail: pranee.r@chula.ac.th

ABSTRACT

*The antibacterial efficacy and preliminary skin irritation test of nano silver finished cotton/polyester blend fabric were evaluated. Bacteriological tests were performed against *Staphylococcus aureus* as a model for Gram-positive bacteria. The results indicated that the antibacterial activity of the treated fabrics, before and after wash, was excellent. Electron microscopy technique was used to observe the nanoscale silver particles. In the animal skin irritation test of the nano silver containing textile, no irritation was observed.*

Key words: Silver, Nanoparticles, Antibacterial activity, Textile, Irritation test

INTRODUCTION

The application of antimicrobial agents on textiles has been started a very long time ago. The historical evidence showed that Egyptians used spices and herbs to preserve mummy wraps. In World War II, German soldiers' uniforms were treated with quaternary ammonium compounds to prevent infection and odour (Smith and Block, 1982). In the last few decades, with the advent of improved human life in the polluted environment, there has been increased interest in antibacterial finishing on textile materials. The control of microbes extends into various areas as the hospital and household clothing.

Textiles made from natural fibers such as cotton are more susceptible to microorganisms than are the synthetic fibers because their hydrophilic structure retains water, oxygen, and nutrients, providing a perfect environment for bacteria growth. The major benefits of antimicrobial finishing for textile are (1) to control the spread of disease and (2) to control the development of odour from perspiration.

Several different classes of antimicrobial agent for textiles have been developed such as phenols, halogen, organometallics, quaternary ammonium salts, and metal salts (Son and Sun, 2003; Nakashima et al., 2001). Silver and its compound have long been recognized for their wide range of antimicrobial activities (Feng et al., 2000). They have been used in the medical field to treat burn infection due to their bactericide properties and low toxicity to human cells. The applica-

tion of nano-sized silver particles onto textiles is a new breakthrough technology. Because of the fact that nanosized material provides greater surface area to volume ratio, small amount of silver nanoparticles can well disperse on the fiber surface.

The aim of this study is to evaluate the antimicrobial activity of cotton/polyester fabric containing silver nanoparticles. The fastness to wash of the finished fabric was also examined. In addition, animal irritation test was conducted as the preliminary evaluation to ensure that it is safe for direct skin contact.

MATERIALS AND METHODS

Materials

In this study, the dyed cotton/polyester blended fabrics (cotton 60% + polyester 40%) supplied from United Textile Mills Company were silver nanoparticles finished by the Metallurgy and Materials Science Research Institute, Chulalongkorn University. The fabrics containing about 1000 ppm of silver were prepared and used throughout the experiments.

Wash fastness test

To evaluate the durability of antibacterial effect after washing, the treated fabrics were cut into the size of 7.5 x 13.5 cm and washed according to AATCC 61(1A)-2001 test method with AATCC Standard Reference Detergent WOB. One cycle of laundering by this method is equivalent to five typical careful hand laundings at temperature of 40±3°C. All the treated samples were subject to 4 cycles consecutive laundering. At the end of the 4th cycle, the samples were rinsed with warm water and air-dried.

Antibacterial test

The antimicrobial activity was quantitatively evaluated against *Staphylococcus aureus* (ATCC 6538), a Gram positive organism, according to AATCC 100 test method. The fabric samples with 4.8±0.1 cm in diameter were placed in a 250 ml glass jar with screw cap and absorbed 1.0±0.1 ml of bacterial inoculum. After incubation over contact periods of 24 hrs, 100 ml of sterilized distilled water was added into the jar and shaken vigorously for 1 min. The solution was then serial diluted to 10¹, 10², 10³, and 10⁴. The diluted solution was plated on a nutrient agar and incubated for 24 hrs at 37±2°C. Colonies of bacteria recovered on the agar plate were counted and the percent reduction of bacteria (R) was calculated by the following equation:

$$R (\%) = (B - A) \times 100 / B \quad (1)$$

where A is the number of bacteria colonies from treated specimen after inoculation over 24 hrs contact period, and B is the number of bacteria colonies from untreated control specimen after inoculation at 0 contact time.

Scanning Electron microscopy

The surface observation of silver nanoparticles finished fabric was carried out with a scanning electron microscope (SEM).

Primary skin irritation test

The material was evaluated for primary skin irritation according to the ISO 10993-10 test method. Three healthy albino rabbits were individually housed. The temperature of the experimental animal room was $20\pm 3^{\circ}\text{C}$ and the relative humidity was controlled at $55\%\pm 15\%$. Approximately 24 hrs before the test, the fur on the backs of the rabbits was clipped. The fabric sample was cut into square shape of 25 mm x 25 mm. The sample was moistened with 0.5 ml distilled water and applied directly to the skin on each side of each rabbit. The control, 25 mm x 25 mm four-ply gauze patch, was similarly applied to each rabbit. Cover the application sites with 25 mm x 25 mm four-ply gauze patch and then wrap with a semi-occlusive bandage for 4 hrs. The appearance of each application site was evaluated at 1, 24, 48, and 72 hrs after removal of the patches.

RESULTS AND DISCUSSION

Antimicrobial activity

Table 1 shows the antimicrobial activities of the nano silver finished cotton/polyester blend fabrics against *S.aureus*. The unwashed treated fabric performed very high activity with >99.99% reduction of bacteria. The durability of antimicrobial ability after repeated launderings is also demonstrated. As shown, the fabric still retained its excellent inhibition to *S.aureus* even after exposure of 4 launderings by standard test method which equivalent to 20 typical careful hand launderings.

Table 1. Antimicrobial evaluation against *S.aureus* of the finished fabrics before and after washed.

Sample	Reduction of bacteria (%)	
	Before washed	After washed ^a
Untreated fabric	0	0
Nano silver treated fabric	>99.99	>99.99

^aThe fabrics were washed according to AATCC test method 61(1A) with 4 laundering cycles.

Scanning electron microscopy (SEM) of the finished fabric

The fiber surfaces of the finished fabrics were observed by SEM. Images of the samples in Fig.1 show the deposition of nanoscaled silver particles on the textile surface. The particles diameter estimated at 100 nm can be seen.

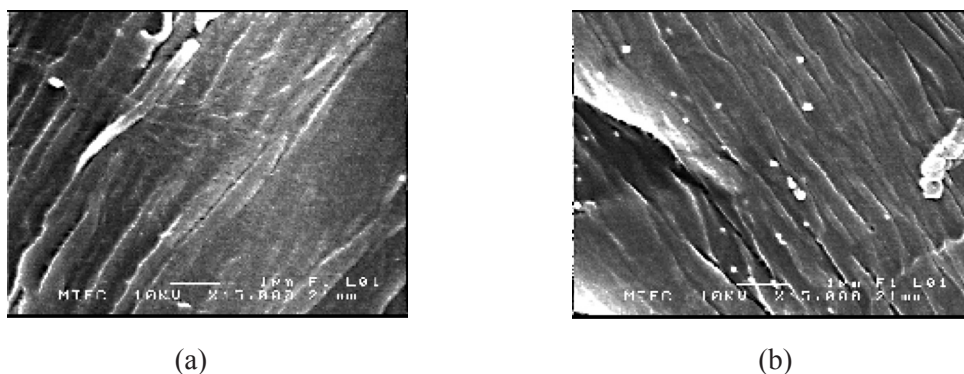


Figure 1. SEM images of (a) untreated (b) nano silver treated fabric.

Primary skin irritation test

Individual results of albino rabbit skin irritation scores are presented in Table 2. Observations were made at 1, 24, 48 and 72 hrs after patch removal. The average oedema score was 0 and the average erythema score was 0 in both sample and control sites.

Table 2. Score of erythema and oedema in albino rabbits after exposure to nano silver finished fabrics.

Rabbit No.		1 hr		24 hrs		48 hrs		72 hrs	
		S	C	S	C	S	C	S	C
1	Erythema	0	0	0	0	0	0	0	0
	Oedema	0	0	0	0	0	0	0	0
2	Erythema	0	0	0	0	0	0	0	0
	Oedema	0	0	0	0	0	0	0	0
3	Erythema	0	0	0	0	0	0	0	0
	Oedema	0	0	0	0	0	0	0	0

Score of skin reaction: 0 = no erythema, 1 = very slight erythema, 2 = slight erythema, 3 = moderate to severe erythema, 4 = severe erythema. Oedema is similarly defined.

*S = Sample site, C = Control site

CONCLUSION

This study shows that the cotton/polyester blend fabrics finished with silver nanoparticles had excellent antibacterial effect against a Gram positive bacteria, *S.aureus*. These findings agree well with the experimental data reported by Lee et al., (2003) and Yeo et al., (2003). Kim et al., (2007) suggested that the inhibitory activity of silver nanoparticles was influenced by free radical generated on the surface of silver nanoparticles.

The result of durability to wash of the treated fabric also showed long-lasting bacteriostatic effect. The *S.aureus* was completely abated on the silver finished textile even after being exposure to 20 consecutive typical careful hand

laundry condition. This verifies that nanosized silver particles, as observed in SEM images, were firmly attached onto the fiber surfaces.

Primary irritation test in rabbit was examined to investigate the effects of dermal exposure of the treated fabric. Based on the results, nano silver treated textile did not show any visible signs of skin irritation.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the National Innovation Agency (NIA) of Thailand, the United Textile Mills Co., Ltd., and the Metallurgy and Materials Science Research Institute (Chulalongkorn University, Thailand) for financial support.

REFERENCES

- Feng, Q. L., J. Wu, G. Q. Chen, F. Z. Cui, T. N. Kim, and J. O. Kim. 2000. A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Staphylococcus aureus*. *J. Biomed. Mater. Res.* 52: 662-668.
- Kim, J.S., E. Kuk, K.N. Yu, J. H. Kim, S. J. Park, H. J. Lee, S. H. Kim, Y. K. Park, Y. H. Park, C. Y.Hwang, Y. K. Kim, Y. S. Lee, D. H. Jeong, and M. H. Cho. 2007. Antimicrobial effects of silver nanoparticles. *Nanomedicine: Nanotechnology. Bio. Med.* 3: 95-101.
- Lee, H. J., S. Y. Yeo, and S. H. Jeong. 2003. Antibacterial effect of nanosized silver colloidal solution on textile fabrics. *J. Mater. Sci.* 38: 2199-2204.
- Nakashima, T., Y. Sakagami, and M. Matsuo. 2001. Antibacterial efficacy of cotton fabrics chemically modified by metal salts. *Biocontrol Sci.* 6: 9-15.
- Smith, B.F. and I. Block. 1982. *Textiles in perspective*. Prentice-Hall, Inc. Englewood Cliffs, NJ, USA.
- Son, Y.A. and G. Sun. 2003. Durable antimicrobial nylon 66 fabrics: Ionic interactions with quaternary ammonium salts. *J. Appl. Polym. Sci.* 90: 2194-2199.
- Yeo, S.Y., H. J. Lee, and S. H. Jeong. 2003. Preparation of nanocomposite fibers for permanent antibacterial effect. *J. Mater. Sci.* 38: 2143-2147.

NONE