

# Properties and Antimicrobial Efficacy of Cellulose Fiber Coated with Silver Nanoparticles and 3-Mercaptopropyltrimethoxysilane (3-MPTMS)

Sam Soo Kim,<sup>1</sup> Jeong Eun Park,<sup>1</sup> Jaewoong Lee<sup>2</sup>

<sup>1</sup>School of Textiles, Yeungnam University, Gyeongsan 712-749, South Korea

<sup>2</sup>Kolon Industries, Inc., Gumi 730-030, South Korea

E-mail: [jeongeun@ynu.ac.kr](mailto:jeongeun@ynu.ac.kr)

## 1. INTRODUCTION

Silver nanoparticles were coated onto cotton fabrics with 3-Mercaptopropyltrimethoxysilane (3-MPTMS). The coating process was accomplished by soaking the cotton fabrics into silver colloid/3-MPTMS solution at 43°C for 90 min. The coated fabrics were characterized by scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS) and thermogravimetric analysis (TGA). SEM images showed a layer of silver nanoparticles and 3-MPTMS on cotton. The XPS data showed that distinguishable binding energy peaks of Ag 3d, Si 2p, Si 2s, S 2p were 368/374, 102, 153 and 162 eV, respectively, which confirms the existence of silver and 3-MPTMS on cotton fabrics. The treated cotton fabrics showed prominent antimicrobial effectiveness against *Staphylococcus aureus* (ATCC 6538) and *Klebsiella pneumonia* (ATCC 4352). Furthermore, the laundry test showed that 66% of silver nanoparticles were retained after 5 washing cycles.

## 2. EXPERIMENTAL

### 2.1. Materials

3-Mercaptopropyltrimethoxysilane (3-MPTMS, 95%) was purchased from Aldrich. Silver colloid (Ag content: 5000 ppm, pH: 9.0±0.5) was obtained from Miji Nanotech (Korea). Isopropanol (95%) was purchased from Duksan chemicals (Korea). All chemicals were used as received without further purification. Desized and bleached cotton fabric (KS K 0905-2008 rule) was obtained from Korea Apparel Testing & Research Institute.

### 2.2. Coating of cotton fabrics with silver nanoparticles and 3-MPTMS

A 0.1mL of 3-MPTMS was added in 10mL of isopropanol. Concurrently 2mL of silver colloid was added in the 3-MPTMS and isopropanol solution to prepare an 830 ppm of silver colloid solution. Cotton fabric (5cm x 5cm) was soaked in the solution followed by shaking in a water bath at 43°C for 90 min. The treated samples were rinsed

with 100mL of propanol two times and then rinsed again with 100mL of distilled water two times. Finally, the samples were air dried at ambient temperature.

## 3. RESULTS AND DISCUSSION

### 3.1. Coating of silver nanoparticles on cotton fabric

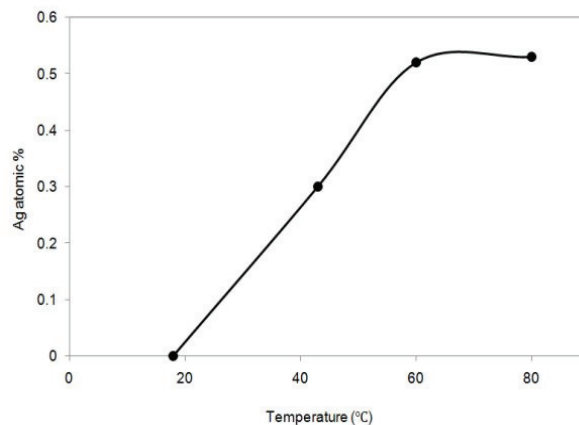
The treatment of cotton fabrics under different concentration of silver colloid with/without 3-MPTMS are shown in Table 1.

**Table 1.** Atomic% of Silver on Cotton Samples Treated with/without 3-MPTMS at 43°C

Concentration of Ag in the solution (ppm)	Atomic% of Ag on treated samples	
	With 3-MPTMS <sup>a)</sup>	Without 3-MPTMS
0	Undetected	Undetected
830	0.11	Undetected
2490	0.30	Undetected
3200	0.28	Undetected
3600	0.29	Undetected

<sup>a)</sup> The amount of 3-MPTMS (95%) was fixed at 0.1 mL.

The treatment of 3-MPTMS and silver nanoparticles on cotton under different temperatures are shown in Fig. 1.



**Fig. 1.** Amount of silver on cotton surface treated with silver colloid and 3-MPTMS at different temperatures

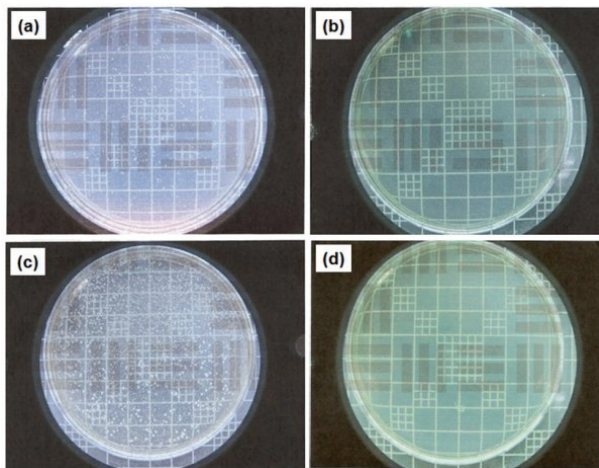
### 3.2. Durability of the treated cotton fabric

**Table 2.** Washing Fastness of Cottons Treated with Silver Nanoparticles and 3-MPTMS

Washing cycles	Retaining of Ag (Atomic%)
0	0.30
1	0.29
2	0.26
3	0.23
4	0.23
5	0.20

### 3.3. Antimicrobial efficacy

In this study, *S. aureus* as a Gram-positive bacterium and *K. pneumoniae* as a Gram-negative bacterium were used to measure antimicrobial activity and the test results are shown in Fig. 2 and Table 3.



**Fig. 2.** Antimicrobial activity of (a) cotton treated with 3-MPTMS against *S. aureus* (b) cotton treated with Silver nanoparticles/3-MPTMS against *S. aureus* (c) cotton treated with 3-MPTMS against *K. pneumoniae*, and (d) cotton treated with Silver nanoparticles/3-MPTMS against *K. pneumoniae*.

**Table 3.** Antimicrobial Test Results of Cotton Fabrics Treated with 3-MPTMS and 3-MPTMS /Silver Nanoparticles

Samples	<i>Staphylococcus aureus</i>		
	Total bacteria (cfu/mL)	Bacterial No. (cfu/sample)	Reduction (%)
Cotton treated with 3-MPTMS	$1.3 \times 10^5$	$6.7 \times 10^4$	48.2
Cotton treated with Silver nanoparticles/3-MPTMS	$1.3 \times 10^5$	0	100
Samples	<i>Klebsiella pneumoniae</i>		
	Total bacteria (cfu/mL)	Bacterial No. (cfu/sample)	Reduction (%)
Cotton treated with 3-MPTMS	$1.5 \times 10^5$	$1.5 \times 10^5$	< 1
Cotton treated with Silver nanoparticles/3-MPTMS	$1.5 \times 10^5$	0	100

## 4. CONCLUSIONS

Silver nanoparticles were successfully coated on cotton fabrics with 3-MPTMS. These treated fabrics were tested for washing fastness and showed reasonable and relatively enhanced durability than pad-dry-cure process which was used no bonding agent. The treated fabrics were also employed for antimicrobial test and the results released that excellent antimicrobial performance against *Staphylococcus aureus* and *Klebsiella pneumoniae*.

## 5. REFERENCES

- [1] Kim, T. K.; Son, Y. Dye Pigments 2005, 64, 85.
- [2] Kim, Y. H.; Sun, G. Tex Res J 2001, 71, 318.
- [3] Ma, M.; Sun, Y.; Sun, G. Dyes Pigments 2003, 58, 27.
- [4] El-Tallawy, K. F.; El-Bendary, M. A.; Elhendawy, A. G.; Hudson, S. M. Carbohydr Polym 2005, 60, 421.
- [5] Lim, S. H.; Hudson, S. M. Carbohydr Polym 2004, 56, 227.
- [6] Kim, Y. H.; Nam, C. W.; Choi, J. W.; Jang, J. J Appl Polym Sci 2003, 88, 1567.
- [7] Zhang, L.; Peng, L.; Su, Z. Mater Chem Phys 2006, 98, 111.
- [8] Takahashi, T.; Shoji, Y.; Inoue, O.; Miyamoto, Y.; Tokuda, K. Biocontrol Sci 2004, 9, 51.
- [9] Lee, J.; Broughton, R. M.; Akdag, A.; Worley, S. D.; Huang, T. S. Tex Res J 2008, 77, 604.