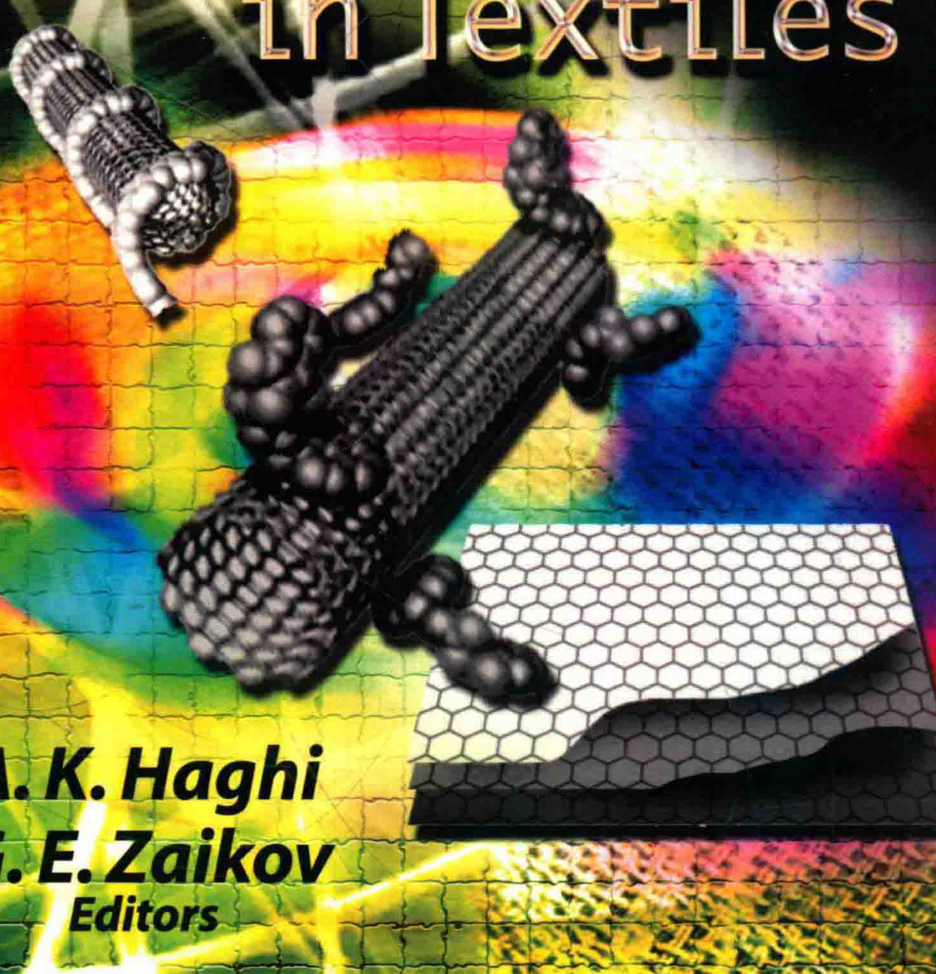
Nanotechnology Science and Technology

Development of Nanotechnology in Textiles



A. K. Haghi
G. E. Zaikov
Editors

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NANOTECHNOLOGY SCIENCE AND TECHNOLOGY

DEVELOPMENT OF NANOTECHNOLOGY IN TEXTILES

A. K. HAGHI
AND
G. E. ZAIKOV
EDITORS

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PREFACE

The textile industry is an early adopter of new ideas and technologies. Textiles are not only for the fashion conscious, they have important applications in the aerospace, automotive, construction, healthcare and sportswear industries. Already on the market are socks and leisurewear with embedded silver nanoparticles that combat odor through killing bacteria – and this capability has been extended successfully to wound dressings.

Across the globe, a tremendous amount of research is taking place in electrospinning techniques. The spun, polymer-based nanofibres can be 'loaded' with different additives which could be nanoparticles, enzymes, drugs or catalysts. Some combinations can be antibacterial and sprayed onto wounds as a kind of healing 'web', others can be conductive or even form filters or membranes.

Scientists are also working on nanoelectronic devices that can be embedded into textiles to provide special support systems for individuals in dangerous professions or sports. Some garments can now provide life-signs monitoring, internal temperature monitoring, chemical sensing and also power generation and storage to enable communication with the outside world. colleagues, or even for skiers or their rescuers to give early warning signs of hypothermia.

Nanotechnology is, broadly speaking, the science of manipulating and rearranging individual atoms and molecules to create useful materials. "Nano" textiles are those designed and engineered on the nanoscale to create specific functions. These nano functions are very diverse and range from UV protection and antibacterial functions to moisture management. The book provides the reader with an overview of the topic.

The subject nanotechnology in textiles is as vast as the universe so to restrict it in a few words is merely impossible. This book summarizes the recent development of nanotechnology in textile areas.

In some establishments, research is ongoing into man-made nanofibers where clay minerals, carbon nanotubes or nanoparticulate metal oxides are used to impart new properties. These properties provide halogen-free, flame retardancy for a fabric, increased strength and shock-absorbency, heat and UV radiation stability, and even brighter coloration.

A.K.Haghi
University of Guilan (Iran)
G.E. Zaikov
Russian Academy of Sciences

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Chapter 1

SILVER NANOPARTICLES PLATING OF FABRICS

M. Saberi Motlagh, V. Mottaghitalab, O. Emamgholipour and A. K. Haghi*
Textile Engineering Dept, Faculty of Engineering,
University of Guilan, Rasht, Iran

1. INTRODUCTION

The coating of metallic particles on polymer surfaces has become an area of interest for many researchers. The coating of polymers using metallic particles in micro and nanoscale extremely enhances the range of their applications for either decorative or superior performance. Regarding this, the applications of textiles as a polymeric substrate are not limited to apparel. This approach provides eye-catching superior functions for textile substrate such as ultraviolet protection, water repellency, electromagnetic interference shielding (EMIS), antistatic behavior and also creates high added value and brilliant decorative effects [1-6].

The common methodology for metal coating consists of the laminating of metal foil, spraying conductive paints and lacquers, sputter coating, flame and arc spraying of metal particles and electroless plating of a variety of metals using chemical reactions.

* Corresponding author: Haghi@Guilan.ac.ir.

Electroless plating was developed to deposit metal from its solution on any kind of substrate without an external current. Metal ions in aqueous solution can be reduced to the metal particles using a reducing agent. Using electroless plating, metallic particles can be deposited even along edges, inside holes, and over rough surfaces which are difficult to be plated [5-10]. Therefore, electroless plating is a preferred way for metal-coating on textiles surface with very high roughness.

In this research, the cotton fabric was metalized by means of silver electroless plating and the final properties of the metalized fabrics were evaluated.

2. Experimental

2.1. Chemical and Reagents

White Cotton fabrics with surface areas of 400 cm^2 (53×48 count/cm^2, 140 g/m^2, taffeta fabric) were used as substrates. A non-ionic detergent, $NaHCo_3$, $SnCl_2$, HCl, $PdCl_2$, $AgNO_3$, NH_4OH, NaOH and α-glucose were used in the electroless plating process.

All chemicals were purchased from Merck and used without any further purification.

2.2. Electroless Plating Procedure

Electroless plating was carried out by multi-step processes including scouring, rinsing, sensitization, rinsing, activation, rinsing, electroless silver plating, rinsing and drying. The fabric specimens (20cm × 20 cm) were first scoured in a non-ionic detergent (2g/l) and $NaHCo_3$ (2g/l) solution at 60°C for 30 min prior to use. The samples then were rinsed in distilled water. Next, surface sensitization was conducted by immersion of the samples into an aqueous solution containing $SnCl_2$ (10g/l) and HCl (40ml/l 38% w/w) at 30°C for 20 min. The specimens were again rinsed in distilled water and immersed in an activator containing $PdCl_2$ (0.1g/l) and HCl (20 ml/l, 38% w/w) at 40°C for 5 min. The specimens were rinsed for a third time in a large volume of deionized water for more than 5 min to prevent contamination of the plating bath. Then all samples were immersed in the electroless bath containing silver nitrate (6g/l), ammonium hydroxide as a complexing agent (10ml/l), sodium hydroxide (4g/l) and α-glucose (4g/l) for 30 min at 60°C. The samples were rinsed in hot and cold water respectively, and then were dried in an oven at 70°C.

2.3. Characterization Techniques

The samples were conditioned under standard atmospheric pressure at 65 ± 2% relative humidity and 21 ± 1°C for at least 24 h prior to all measurements.

The changes of fabric weight before and after the plating procedure were determined by a digital weighing scale (HR200, AND Ltd., Japan). The percentage change of fabric weight was calculated by Eq. (1) as follows:

$$\text{Weight change (\%)} = \frac{W - W_0}{W_0} \times 100 \tag{1}$$

The fabric thickness was measured via digital thickness gauge (M034A, SDL Ltd., England) before and after coating. After measurement, the change in thickness can be calculated by Eq. (2) to show the change of fabric thickness.

$$\text{Change in thickness (\%)} = \frac{T - T_0}{T} \times 100 \tag{2}$$

According to ASTM D1388-2001, flexural rigidity of cotton fabric before and after plating was calculated. Stiffness tester (003B, SDL Ltd., England) was employed to measure the length of bending of the fabric in both warp and weft directions. The flexural rigidity was calculated by Eq. (3).

$$G = 0.1 \times M \times C^3 \tag{3}$$

M is the mass of fabric per unit area and C is the bending length.

The tearing strength and elongation of the silver-plated cotton fabric was assessed by (Micro 250, SDL Ltd., England) under constant elongation rate according to ISO 13934-1:1999 standard.

The crease recovery angle of the cotton fabric was measured by crease recovery tester (M003A, SDL Ltd., England) before and after electroless plating according to BS EN 22313:1992 standard.

To study the surface morphology of the cotton fabric before and after plating, the SEM images were recorded by a Philips SEM model 515. The SEM picture of the fabric surface was measured at a magnification of 625 and 10000×. Furthermore, the wave length dispersive x-ray spectrometry (WDX) images were recorded using Microspec, 3PC.

Fourier transform infrared (FTIR) spectra before and after silver coating were acquired by means of Nicolet Magna-IR 560, in the range from 4000 to 500cm^{-1} with 100 scansions and 4 cm^{-1} of band resolution.

The surface resistance of prepared fabric samples was measured by a homemade four-probe apparatus with 1 cm inner distance between four electrodes. Random areas of both the front and back surfaces of the silver-plated fabrics were measured. The measurement carried out was based on ASTM standards F43-93.

The ISO 105-C06:1994 (color fastness to domestic and commercial laundering) standard was used to estimate the effect of washing fastness on the surface resistance and discoloration of plated fabric.

The effect of wet and dry rubbing fastness tests on the color and surface resistance of coated fabric, the electric crockmeter (M238B, SDL Ltd., England) was employed. Wet and dry rubbing fastness was carried out according to ISO 105-X12:2001 standards.

Color fading and surface resistance of coated fabric was assessed by perspiration fastness tests in both acidic and basic solutions under ISO 105-E04:1994 standard conditions.

3. Results and Discussion

3.1. Fabric Characteristics

The fabric weight, thickness and stiffness before and after the coating process were calculated using Formulas 1, 2 and 3, shown in Table 1. The results show that coated fabric was heavier and thicker than the original one. The measured percentage of changes in weight and thickness were 23 and 15, respectively. Thus, it could be demonstrated that silver ions had stuck to the fabric surface impressively. In addition, it could be demonstrated that the silver-plated cotton fabric was stiffer than the untreated one. Bending of the fabric depended on surface friction between the fabric yarns and fibers. After electroless silver plating, the presence of the silver particles on the fibers surface increased the friction between fibers and restricted their relative movement. In consequence, the stiffness of the cotton fabric would increase after silver coating.

Table 1. Measurement of fabric weight, thickness and bending

Specimen (10cm×10cm)	Weight(g)	Thickness(mm)	Flexural rigidity (mg.cm)	
			Warp	Weft
Before plating	1.4	0.4	103.8	68.8
After plating	1.72(↑23%)	0.46(↑15%)	112(↑7.9%)	88.6(↑28.8%)

The estimation of fabric tearing strength, tearing elongation and crease are illustrated in Table 2. According to the obtained results, the tearing strength and tearing elongation of the cotton fabric decreased and increased, respectively, after silver plating. The decreasing of tearing strength and increasing of tearing elongation are the consequence of fabric exposure to highly low pH medium during sensitization and the activation process. The cotton fiber interbonding will be damaged in low pH value resulting in the weakness of the cotton fabric. The values of the crease recovery angle shows a significant improvement for the crease resistance property of cotton fabric after silver electroless plating in both wrap and weft direction. Although the friction between fabric yarns and fibers increased after plating and it seems that the crease recovery angle should decrease, the cotton fabric presence of silver particle on the surface of fibers prevented the creation of the hydrogen bond between cotton fibers during wrinkle implementation. According to obtained results, silver plating on cotton fabric decreases retained crease and enhances wrinkle recovery of the cotton fabric.

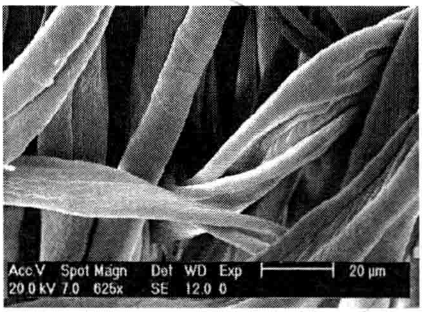
Table 2. Estimation of fabric tearing strength, tearing elongation and crease

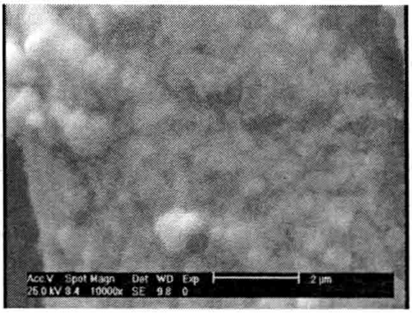
	Tearing strength(kg.f)	Tearing elongation(mm)	Crease Recovery(degree°)	
			Warp	Weft
Before plating	1667.1	5.47	35	30
After plating	1553.7(↓6.8%)	8.05(↑47.2%)	40(↑14.3%)	32(↑6.67%)

Table 3 summarized the results of estimation of color change after washing, rubbing and perspiration. According to the obtained results, washing and perspiration have no influence on the color of plated fabric. The color fastness results of washing and perspiration are rated as grade 5. The result of rubbing fastness reveals that color of coated fabrics partially changed after dry rubbing. This showed that some silver particles were detached during dry rubbing; likewise, the results show wet rubbing fastness of the plated fabric was comparatively poor considering commercial necessity.

Table 3. Estimation of color change

Washing	Rubbing		Perspiration	
	Dry	Wet	pH 5	pH 8
5	3-4	3	5	5





3.2. Fabric Resistance

The surface resistance measurement showed that the resistance of fabric was changed from ∞ to approximately 5.2×10^{-4} Ω/sq which illustrated a remarkable change in surface resistance of silver electroless plated cotton fabric. Results reported in previous studies [1-10], show that surface resistivity of cotton fabric after silver electroless plating was changed from ∞ to 14.9MΩ; in their research, the cotton surface was activated by stannous chloride.

In this work, catalytic sites on the fabric surface were created by proceeding the activation process in which palladium ions are reduced on the surface by stannous ions to a palladium layer that act as a catalyst stead stannous layer for the ensuing electroless deposition of silver. Therefore, in comparison of results, significant development in the surface resistance of electroless silver plating on the cotton fabric could be illustrated by using palladium chloride as an activator agent stead stannous chloride.

The effect of washing on the surface resistance of plated fabric is illustrated in Figure 1. As shown in Figure 1, although the surface resistance of plated fabric after each washing repetition became less, the slope of resistance increasing is downward; furthermore, the change in surface resistance of the coated fabric was negligible.

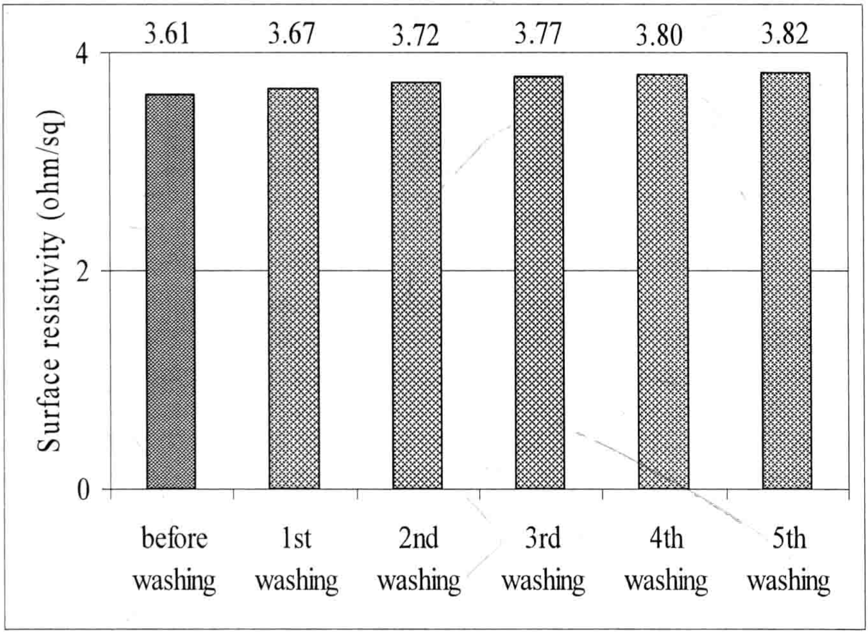


Figure 1. Effect of washing on the surface resistance of silver-plated cotton fabric.

Figure 2 shows the influence of both dry and wet rubbing on the surface resistance of silver-plated cotton fabric. According to the results shown in Figure 2, by reiteration of both dry and wet rubbing tests, the difference of surface resistance between the first and fifth test is insignificant, but meaningful differences appeared in surface resistance of silver-plated fabric observed after first dry and wet rubbing tests compared to the untested one. The surface resistance of coated fabric before the rubbing test was 3.61Ω/sq which decreased after dry and wet rubbing tests to 4.74Ω/sq and 6.10Ω/sq, respectively, which indicates detaching of silver particles from the fabric surface in the first rubbing test; nevertheless, the silver-plated cotton fabric has considerable surface resistance than the uncoated one.

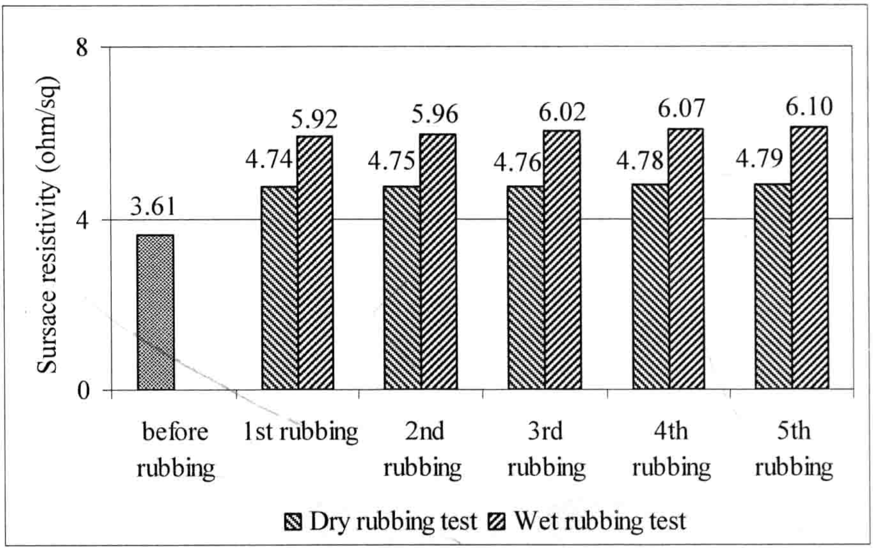


Figure 2. Influence of rubbing on the surface resistance of silver-plasted cotton fabric.

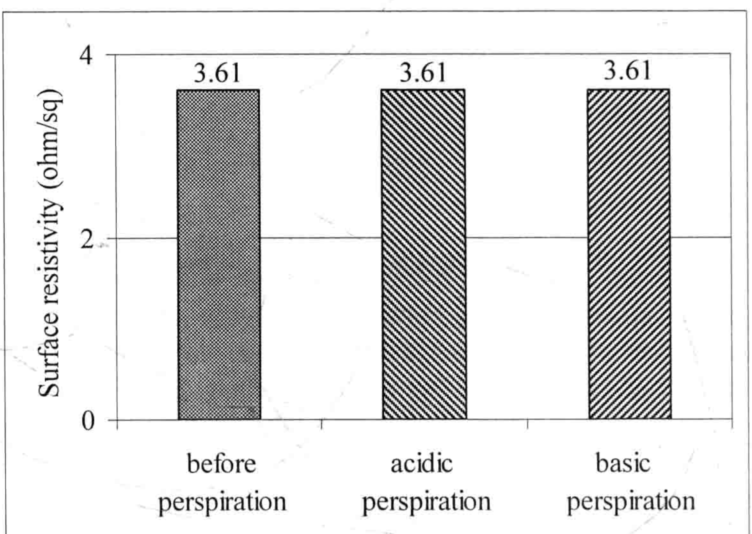


Figure 3. Effect of perspiration on the surface resistance of silver-plated cotton fabric.