INVESTIGATION ON ANTIBACTERIAL ACTIVITY OF COTTON SILVER COATED FABRIC AFTER DYEING

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Abstract: In this research work, the cotton fabrics were sputtered using DC magnetron sputtering system for different times of exposure by silver. Then the silver coated samples were dyed by different classes of synthetic and natural dyes. The dye ability of coated samples was compared with untreated cotton. The reflective spectrophotometer was used for this purpose. The morphology of the cotton fabrics before and after dyeing was observed using a scanning electron microscope (SEM). The antibacterial activity of samples before and after dyeing, were investigated and compared. For antibacterial investigation, the agar test (Halo method) is a well-established method to provide a semi-quantitative analysis. Also the antibacterial counting tests were used. Very good antibacterial activity was achieved and the details will be discussed in full paper.

1. Introduction

Cotton is a natural fiber that consists of cellulose with 1,4-Dglucopyranose as its repeat unit. Cotton textiles are highly popular with people because they are next to skin, sweat-absorbing, and comfortable. However, cotton fabrics provide an excellent environment for microorganisms to grow owing to their ability to retain moisture. Therefore, numerous chemicals have been used to improve the antimicrobial activity of cotton textiles. Among these antimicrobial agents, metal particles such as silver and copper have been widely used in many fields because it shows strong biocidal effects on many pathogenic bacteria. In addition, nanosized inorganic particles possess high surface area/volume ratio and display unique physical and chemical properties. Accordingly, the immobilization of metal nanoparticles on various fibers has recently attracted a great deal of attention. However, some difficulties during the handling of nano particles (agglomeration, nano toxicology) and concerning the distribution of nano particles at the surface as well as mechanical durability occur. Nanoporous structures, on the other hand, which can be obtained by plasma sputtering processes might avoid these issues and yield an even higher surface area. Furthermore, nano particles with homogeneous size and spatial distribution can also be embedded in situ by a plasma sputtering process.

Conventional finishing techniques applied to textiles (dyeing, stain repellence, flame retardance, antibacterial treatments) generally use wet-chemical process steps and produce a lot of wastewater [1, 2].

In our previous research work, we had shown that, Plasma sputtering treatment as a dry and eco-friendly technology, is offering an attractive alternative to add new functionalities such as antibacterial properties due to the nano-scaled modification on textiles and fibers.[3] At the same time, the bulk properties as well as the touch of the textiles remain unaffected.[4-10]

It should be mentioned that, the dyeability of textiles is very important feature. So in this research work, the dye ability of nano-coated samples was investigated. Also the optical properties and color changes of dyed coated samples are studied.

2. Experimental part

The samples used in this investigation were Plain-weave 100% Cotton fabrics supplied by the Baft Azadi Co (Tehran, Iran). Before LTP treatments, in order to minimize the chance of contamination, samples were washed with 1% nonionic detergent solution in 70 ^{o}C water for 15 min and then rinsed with water for another 15 min, and dried at room temperature. The cotton fabrics were divided to two parts. Some of them were sputtered using plasma sputtering system for different times of exposure by silver, and then the nano coated samples were dyed by different classes of synthetic dyes. The dye ability of coated samples was compared with untreated cotton. The rest of samples first were dyed and then sputtered by nano-layer of mentioned metal particles.

The deposition of the metal layer (silver) was realized using a magnetron sputter device with a DC sputter source on a laboratory scale. The schematic of the Dc magnetron sputtering were shown elsewhere [11, 12]. The sputtered metal particles were deposited on the surface of the fabrics, which were placed on the anode. The system was evacuated to 2×10^{-5} Torr by a rotary and turbo pumps before plasma treatment. Then the gas (argon) was admitted up to 2×10^{-2} torr. The duration of plasma sputtering was 150 and 300 seconds, respectively.

The fabrics were dyed using Acid, Basic, reactive and direct dyes as a synthetic dyestuffs. For synthetic dyeing processes, aqueous solutions, containing 3.0 wt.% of the dye were employed. The bath ratio was 1:30 (1 g of fiber in 30 ml of dye solution). The following dyeing conditions were adopted: For Direct, Anionic and Cationic dyeing processes: Initial temperature 40 ^{o}C, followed by a temperature increase of 3 ^{o}C.min^{-1} up to 80 ^{o}C, holding for 30 min at 80 ^{o}C. 30 g/ lit NaCl were included in the direct dyeing medium. 5 g/lit of acetic acid for pH adjustment, were added for anionic dyeing processes. After dyeing, the fabrics were rinsed with cold hot-cold water and then dried at room temperature. After preparing the samples, Color intensities of the dyed fabrics were measured by using a UV VIS-NIR Reflective Spectrophotometer, over the range of 200-800 nm. And the reflection factor (R) was obtained. The relative color strength (K/S value) was then established according to the following Kubelka-Munk equation (2), where K and S stand for the absorption and scattering coefficient, respectively:

$$K/S: \{(1-R)^2/2R\} \quad (1)$$

For Bacteria counting test, Luria Bertani media (LB) broth was used as growing medium for Staphylococcus aurous. Bacteria were dripped in 10 mL of LB broth to reach a cell concentration of 1×10^8 (CFU)/mL. Then it was diluted to a cell concentration of 1×10^6 (CFU)/mL. 1cm×1cm size fabric sample was cut and put into 1mL Bacteria suspension. All samples were incubated for 24 h at 37^{o} C. From each incubated sample, 100 µL of solution was taken and distributed onto an agar plate. All plates were incubated for 24 h and colonies formed were counted. The percentage reduction was determined as follows:

$$\text{Reduction (\%)} = (C-A)/C \quad (2)$$

Where C and A are the colonies counted from the plate of the control and treated sample, respectively.

3. Results and discussion

By plasma sputtering as a dry and eco-friendly technology, antibacterial activity has been developed, through incorporation of metal nano particles on fabric surfaces. The antibacterial activity of samples were investigated and compared. For antibacterial investigation, the agar test (Halo method) is a well-established method to provide a semi-quantitative analysis. Also the antibacterial counting tests were used. Just by 150 seconds of deposition very good durable antibacterial properties gained on the cotton fabrics (Figure 1).

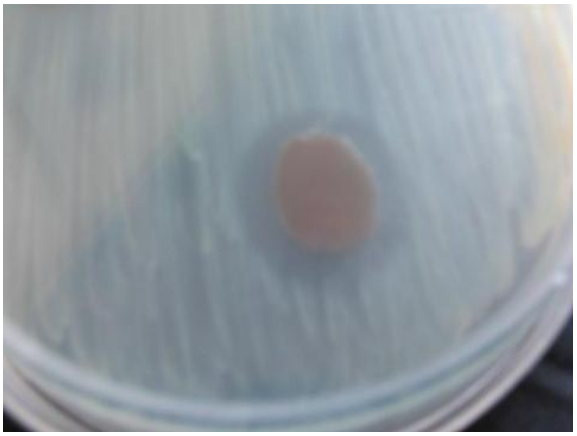

Figure 1: Inhibition Zone (Antibacterial activity) of Ag-nano- coated cotton.

The results related to bacterial counting test is shown in Figure 2. As it can be seen, by 150 seconds of plasma sputtering, No bacteria can spread over the agar plate. It means that, by silver sputtering on the surface of cotton samples, all the bacteria colonies were killed. Also it should be mentioned that, the dyed samples show the same results. The antibacterial efficiency of dyed sputtered samples will remain constant as compare with sputtered without dyestuff one.
In Figure 2, just the bacterial counting results of silver sputtered sample is shown, since the results for the rest of dyed and undyed sputtered samples are similar.

Figure 2: The Bacterial counting test result

It should be mentioned that, the dyeability of the fabrics play very important role in textile industry. So in this research work the dyeing properties of cotton nano coated samples with different classes of dyestuffs were investigated.

Color intensities and optical properties of dyed fabrics were measured using a UV–VIS–NIR Reflective Spectrophotometer (Varian, Carry 500), over the range of 400–700 nm. The results of sputterd sample after dyeing are shown in Figure 3- 6.

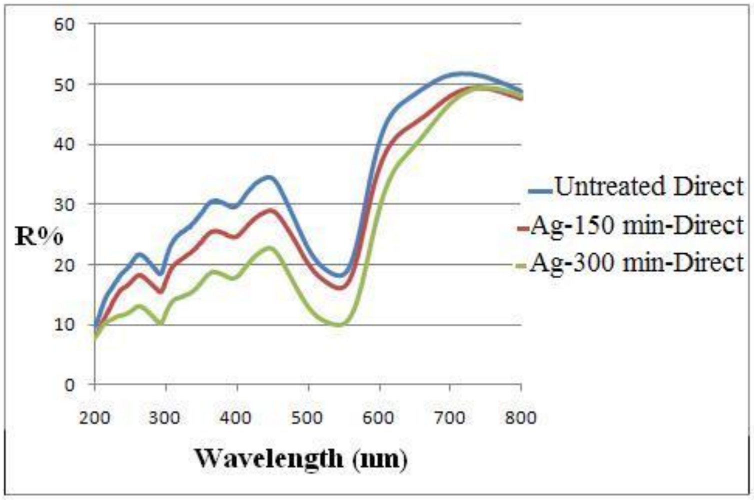

Figure 3: The reflection spectroscopy results for untreated and sputtered samples after dyeing with Direct dye

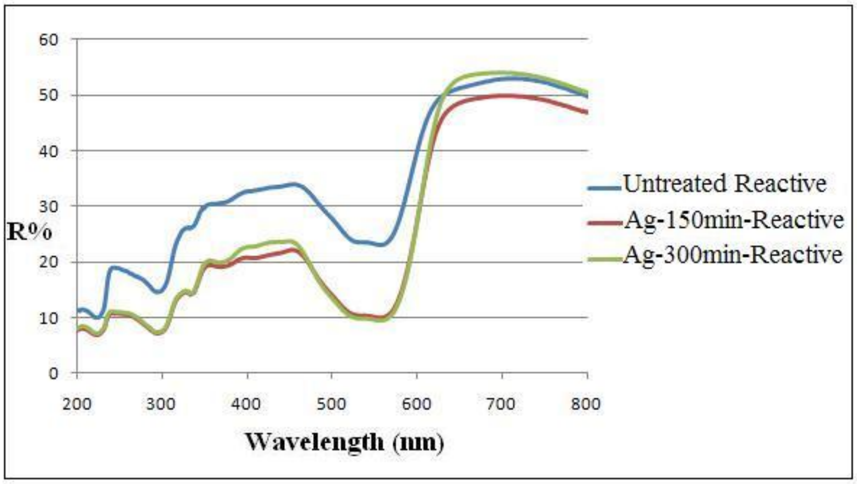

Figure 4: The reflection spectroscopy results for untreated and sputtered samples after dyeing with Reactive dye

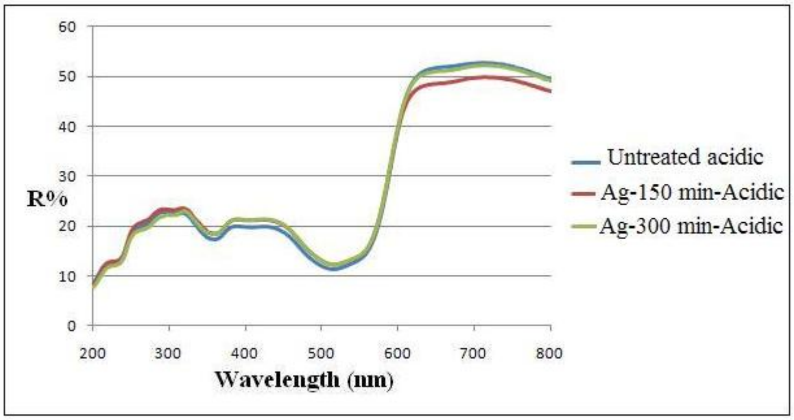

Figure 5: The reflection spectroscopy results for untreated and sputtered samples after dyeing with Acid dye

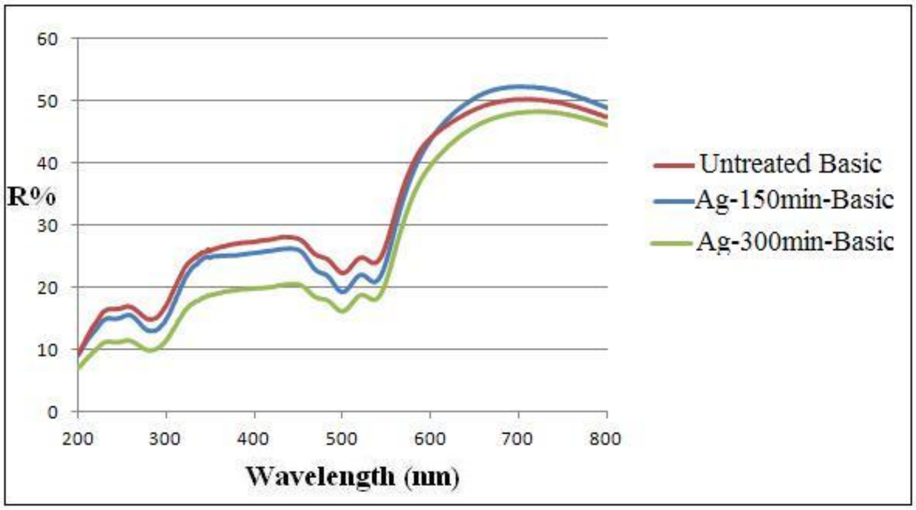

Figure 6: The reflection spectroscopy results for untreated and sputtered samples after dyeing with basic dye

As it can be seen, the sputtered samples can be dyed easily with different classes of dyestuffs similar to untreated cotton. In some cases as it is seen in Figure 3 and 4, the sputtered samples can absorb more amount of dyestuff as compare with untreated cotton.

The results show that, the affinity of cotton samples to some classes of dyes are increased by presence of metal nano particles on the surface. However, the chemical structure of dyestuff is very important factor. Also, it can be seen that, by plasma sputtering on the surface of cotton samples, the reflection factor will be decreased. It means that, the samples seem darker.

4. Conclusion

In this research work, cotton fabrics were sputtered using plasma sputtering system for different times of exposure by silver, and then the nano coated samples were dyed by different classes of synthetic dyes. In this study, we have used a DC magnetron sputtering system for creating antibacterial properties on cotton fabrics. In addition, the dyeability and optical properties of samples were investigated. The results show that, the dyeability of cotton samples to some classes of dyestuffs is increased by presence of metal particle on the surface of sample.

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