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THE ANTIFUNGAL ACTIVITY OF CORONA TREATED POLYAMIDE AND POLYESTER FABRICS LOADED WITH SILVER NANOPARTICLES

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Abstract. This study is aimed to highlight the possibility of using the corona treatment for fiber surface activation that can facilitate the loading of silver nanoparticles from colloids onto the polyester and polyamide fabrics and thus enhance their antifungal activity against *Candida albicans*. Additionally, the laundering durability of achieved effects was studied. Corona activated polyamide and polyester fabrics loaded with silver nanoparticles showed better antifungal properties compared to untreated fabrics. The positive effect of corona treatment became even more prominent after 5 washing cycles, especially for polyester fabrics.

1. INTRODUCTION

The interests for the manufacturing of sportswear, medical and protective textiles with antimicrobial properties increased in the last several years. Different textile materials loaded with silver nanoparticles (NPs) as antimicrobial agents can provide desirable antimicrobial efficiency (see e.g. Pohle et al. 2001, Yuranova et al. 2006). However, the most of these materials are based on synthetic fibers, which are often highly hydrophobic. Higher accessibility of hydrophobic fibers to various chemical species can be obtained by plasma functionalization and plasma etching. Therefore, improved loading of silver NPs from colloids and enhanced interaction between hydrophilic silver NPs and hydrophobic fabrics can be achieved by appropriate plasma treatment.

In this study, we discuss the possibility of using the corona treatment for fiber surface activation, which can facilitate the loading of silver NPs from colloids onto the polyester (PES) and polyamide (PA) fabrics and thus, improve their antifungal activity against *Candida albicans*. Additionally, the laundering durability of obtained antifungal effects was examined.

2. EXPERIMENTAL

The experiments were performed on desized and bleached polyester (PES, 165 g/m^2) and polyamide (PA, 150, g/m^2) fabrics, which were cleaned as described elsewhere (see e.g. Radetic et al.).

Corona treatment of fabrics was carried out at atmospheric pressure using a commercial device Vetaphone CP-Lab MK II. Fabrics were placed on the electrode roll covered with silicon coating, rotating at the minimum speed of 4 m/min. The distance between electrodes was 2 mm. The power was 900 W and the number of passages was set to 30.

$AgNO_3$ and $NaBH_4$ were used for the synthesis of colloid of silver NPs (50 ppm) as described elsewhere (see e.g. Radetic et al.). One gram of fabric was immersed in 65 mL of colloid of silver NPs for 5 min and dried at room temperature. After 5 min of curing at 100 °C, the samples were rinsed twice (5 min) with deionized water and dried at room temperature. The whole procedure was repeated twice on each fabric.

Fiber morphology was observed by scanning electron microscope (SEM) JEOL JSM 6460 LV.

The contact angle of water in air on the surface of fabrics was measured by Krüss tensiometer K12.

The antifungal properties of fabrics were quantitatively evaluated using a *Candida albicans*. 70 mL of sterile potassium hydrogen phosphate buffer solution (pH 7.2) was inoculated with 0.7 mL of a fungal inoculum. One gram of sterile fabric cut into small pieces was put in the flask and shaked for 1 h. 1 mL aliquots from the flask were diluted with phosphate buffer and 0.1 mL of the solution was placed onto a tryptone soy agar (Torlak, Serbia). After 24 h of incubation at 37 °C, the zero time and one hour counts of viable fungi were made. The percentage of fungi reduction (R, %) was calculated in accordance to equation:

$$R = \frac{C_0 - C}{C_0} \tag{1}$$

where C_0 is the number of fungi colonies on the control fabric (untreated fabric without Ag) and C is the number of fungi colonies on the fabric loaded with silver NPs. Laundering durability of antifungal effects was determined after five cycles of washing (see e.g. Radetic et al.).

3. RESULTS AND DISCUSSION

In order to improve the interaction between hydrophilic colloidal silver NPs and hydrophobic fibers, corona treatment of PA and PES fabrics was performed. Contact angles of untreated PES and PA fabrics were 89° and 83°, respectively. However, contact angles decreased to 56° for PES fabric and to 76° for PA fabric after corona treatment, demonstrating that the fibers became more hydrophilic due to the oxidation of the fiber surface and the formation of new polar functional groups.

In addition to changes in wettability of fibers, corona treatment induced the changes in surface morphology, which were assessed by SEM. SEM images of untreated and corona treated PES and PA fibers are shown in Fig. 1. It is evident that both, untreated PES and PA (Fig. 1a and 1b) fibers have smooth surfaces. The ripple-like structure of submicrometer-size was developed on the surface of corona treated PES

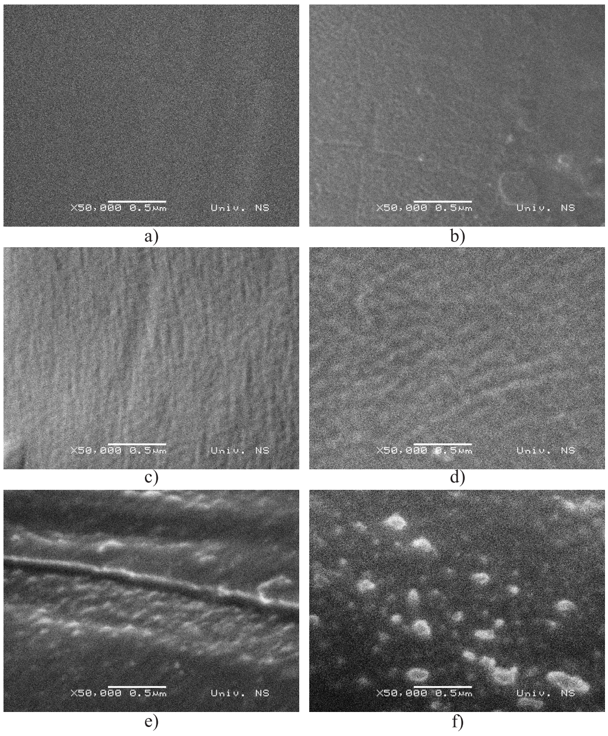

Figure 1: SEM images of a) untreated PES; b) untreated PA; c) corona treated PES; d) corona treated PA; e) corona treated PES loaded with silver NPs and f) corona treated PA loaded with silver NPs.

and PA fibers (Fig. 1c and 1d). Corona treatment increased the fiber surface area and the surface roughness. Corona induced morphological changes that can be attributed to fiber etching, which occurred as a consequence of a severe bombardment of fiber surface by particles generated by the plasma.

SEM technique was also used for analysis of fibers loaded with silver NPs from colloids. Deposition of silver NPs (Fig. 1e and 1f) led to a formation of granular structure on the surface of corona treated PES and PA fabrics.

To evaluate the antifungal activity of PA and PES fabrics loaded with silver NPs from colloids, tests with *Candida albicans* were accomplished. Fungal reduction of untreated (UPA and UPES) and corona treated (CPA and CPES) fabrics loaded with silver NPs before and after 5 washing cycles is presented in Table 1. Fungal reduction of UPES fabrics was higher by 3.9% compared to UPA fabrics. Apparently, corona treatment considerably contributed to increase in antifungal efficiency of both fabrics. The positive effect of corona treatment was more pronounced in the case of PA fabrics. Antifungal efficiency of corona treated fabrics after 5 washing cycles was remarkably higher in comparison with untreated fabrics. Silver loaded PES fabrics showed considerably better laundering durability than PA fabrics. Obtained results are in good correlation with our previous study on bacterial reduction for *Escherichia coli* and *Staphylococcus aureus* (see e.g. Radetic et al.).

Table 1: Antifungal efficiency of PES and PA fabrics loaded with silver NPs. C_i - Initial number of fungal colonies, C_{f1}-Number of fungal colonies on the fabric (before washing), C_{f2}- Number of fungal colonies on the fabric (after washing)

Sample	C_i	C_{f1}	R, %	C_{f2}	R, %
Control PES		$6.3\ 10^4$		$6.3\ 10^4$	
UPES+Ag		$1.9\ 10^3$	97	$9.0\ 10^3$	85.7
CPES+Ag	$4.2\ 10^5$	$5.6\ 10^2$	99.1	$2.1\ 10^3$	96.7
Control PA		$1.9\ 10^5$		$1.9\ 10^5$	
UPA+Ag		$1.3\ 10^4$	93.2	$8.4\ 10^4$	55.8
CPA+Ag		$1.6\ 10^2$	99.9	$6.7\ 10^4$	64.7

4. CONCLUSIONS

Deposition of silver NPs from colloids provided excellent antifungal effect for *Candida albicans* to PA and PES fabrics. Untreated PES fabrics loaded with silver NPs showed better antifungal efficiency than PA fabrics. Corona treatment positively affected the antifungal efficiency especially of PA fabrics loaded with silver NPs. The contribution of corona treatment to improvement of antifungal efficiency of both fabrics became even more prominent after 5 washing cycles. The antifungal effect of silver loaded PES fabrics which were corona pretreated was slightly altered after washing, indicating the excellent laundering durability.

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