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SHORT COMMUNICATION

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ANTIMICROBIAL TEXTILE PREPARED BY SILVER DEPOSITION ON DIELECTRIC BARRIER DISCHARGE TREATED COTTON/POLYESTER FABRIC

The objective of this research was to impart the additional value on cotton/ /polyester (Co/PES) fabrics (i.e. antimicrobial properties) to improve the quality of life and thus to tap new markets with the product. In this paper, silver ions were incorporated in Co/PES fabrics by chemisorptions into the fabric previously treated in a dielectric barrier discharge (DBD). A series of the DBD fabric treatments were done in order to determine the most suitable experimental conditions for the DBD activation of the fabric surface, while the optimal conditions for silver ions sorption by Co/PES fabrics were determined by changing sorption conditions. The antimicrobial Co/PES fabrics prepared by dielectric barrier discharge mediated silver deposition show an antimicrobial activity against tested pathogens: S. aureus, E. coli, and C. albicans under in vitro conditions. The obtained results confirm the practicability of the plasma modification process and furthermore show that with some delays in the next step, i.e. silver ion sorption, we can get the increase in the amount of the sorbed silver ions; the maximum sorption capacity of modified Co/PES fabrics was 0.135 mmol of Ag^+ ions per gram of a fabric.

Key words: antimicrobial textiles; cotton/polyester fabric; dielectric-barrier discharge; silver ions; antimicrobial testing.

It has long been recognized that micro organisms can grow on textile substrate. One way to avoid the microbial degradation of textile fibers, limit the incidence of bacteria, and protect users, is the treatment of textiles with antimicrobial agents [1,2]. Silver in various forms has a long history as an antimicrobial agent and silver-loaded fibers deserve special attention due to some unique properties, which differentiate silver from other antimicrobial additives, namely its inherent properties of high thermal stability, broad and long-term activity; bacteria are not able to develop their resistance to the silver, as in the case of antibiotics; and it is one of a few antimicrobial preparations which possess both the antibacterial activities and antifungal properties [3,4].

There are numerous ways by which antimicrobial properties can be accomplished in textiles: the incorporation of antimicrobial agents directly into fibers, coating or adsorbing antimicrobials onto fiber surfaces, the immobilization of antimicrobials to fibers by ion or covalent linkages, *etc*. Among all these, plasma-based treatments used to create antimicrobial coatings on textile deserve special attention due to some unique properties and growing demands on the environmental friendliness of finishing processes for surface modification and coating of textiles [5,6].

The objective of this research is to impart the additional value on cotton/polyester (Co/PES) fabrics (*i.e.*, antimicrobial properties), to improve the quality of life and thus to tap new markets with the product. In this research, silver ions were incorporated into Co/PES fabric previously treated in a dielectric barrier discharge (DBD). A series of the DBD fabric treatments were done in order to determine the most suitable experimental conditions for the DBD activation of the fabric surface, while the optimal conditions for silver ions sorption by Co/PES fabrics were determined by changing sorption conditions. Antimicrobial activity of modified Co/PES fabrics against different pathogens was evaluated *in vitro.*

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EXPERIMENTAL

The tested fabric was a commercial Co/PES fabric, consisting of 50 % cotton and 50 % polyester, plain weave, with a fabric weight of 250 g/m^2 and a thickness of 0.68 mm. All chemicals used are p.a. grade.

In this work, DBD with plane-parallel electrodes (8.0×8.0 cm) for operation in ambient air at atomspheric pressure was used. The configuration of the electrodes is presented in Figure 1. Spherical zeolite granules cover the bottom electrode of the DBD, in one layer, to avoid problems with humidity and to maintain a homogeneous discharge [7]. The Co/PES fabric sample strips (15×80 mm long, in warp direction) were treated using the DBDs for different period of time (up to 120 s). Antimicrobial Co/PES fabrics were obtained by silver ion sorption from aqueous silver nitrate solution; the subsequent silver sorption by plasma treated fabrics has taken place immediately after the DBD treatment or after 1, 3, and 7 days of aging. The amount of sorbed Ag^+ was determined by the back titration according to Volhard's method [8]. Agar diffusion test was used to assess the antimicrobial activity of silver - loaded cotton/polyester fabric [9,10]. Three test organisms were used: Gram-positive *Staphylococcus aureus* ATCC 25923, Gram-negative *Escherichia coli* ATCC 25922, and yeast *Candida albicans* ATCC 24433.

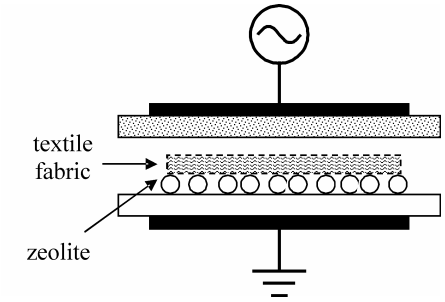

Figure 1. The configuration of the electrodes.

RESULTS AND DISCUSSIONS

Plasma surface activation is initiated by radical reactions of the plasma-activated gases or plasma-generated UV-irradiation. The modification of a textile surface by atmospheric-pressure DBD plasmas mainly depends on the gas nature and the exposure time. In this study, the air was chosen as the operating gas because of the economic reason and the reactivity of the oxygen (*i.e.*, the molecular oxygen in the air can be converted into reactive atomic oxygen radicals or excited ozone molecules), and the surface modification induced on Co/PES fabrics by DBD treatment was investigated as a function of the exposure time.

The silver ion sorption used to obtain antimicrobial fabrics, was also used as a measure of the surface activation of DBD modified fabrics, which is directly related to the surface ion exchange functions. Because of the common observation that the chemical and physical activity of the plasma activated polymeric surfaces diminishes with time [11,12], the subsequent silver sorption by plasma treated fabrics has taken place immediately after the DBD treatment or after 1, 3, and 7 days of aging (Figure 2). In that way we evaluated the practicability of the process because it has to be tolerant to short storage times and typical delays in the manufacturing process.

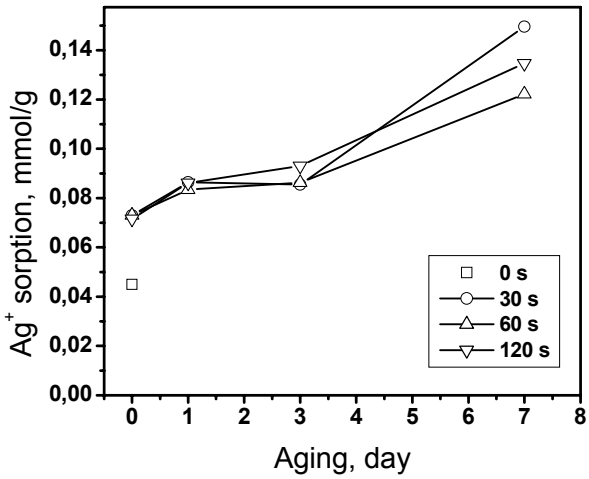

Figure 2. The effects of the plasma exposure time and aging on Ag^+ sorption by DBD activated Co/PES fabrics (sorption: RT, 4 h, pH 5.1, 0.01 M $AgNO_3$).

Co/PES fabrics treated in DBD possess highly improved sorption properties. The obtained silver ion uptakes immediately after plasma treatments were ≈100 % higher than the silver ion uptake of an unmodified fabric, as shown in Figure 2. However, there is no clear exposure time dependant silver ions uptake under the applied experimental conditions. At the same time, the silver ion uptake of the aged DBD treated samples gradually increased for about 50 to 100 % with the aging time, up to 7 days of aging. The observed increase of the amount of silver ions sorbed by the aged DBD treated Co/PES fabrics can be explained by post-plasma reactions (*i.e.*, further oxidation of the carbonyl to the carboxyl function) generated by quite stable radicals [7,12,13].

The effect of the contact time on the silver ions uptake was studied up to a contact time of 4 h (Figure 3). The fast sorption of Ag ions was observed in the first 60 min; approximately more than 90 % of the total uptake capacity of silver ions was sorbed within this period of time. The generally fast sorptions indicate that

reactions at outer surfaces are important. After this equilibrium period the amount of sorbed silver ions did not change significantly with an increase in contact time.

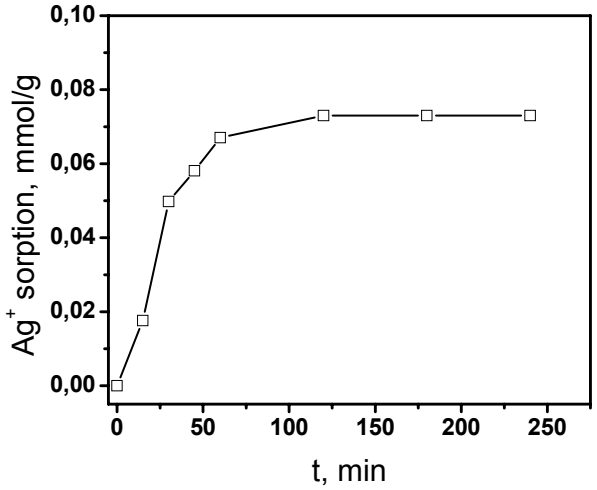

Figure 3. Kinetics of Ag^+ sorption by 60 s DBD modified Co/PES fabric immediately after the treatment (sorption: RT, pH 5.1, 0.01 M $AgNO_3$).

The results of antimicrobial tests given in Table 1 show that the incorporation of silver ions in Co/PES fabric leads to the generation of antimicrobial materials having the activity against a broad spectrum of microbes (Gram-negative bacteria strains - *E. coli*, Gram--positive bacteria strains - *S. aureus*, and yeast - *C. albicans*). These fabrics indicate a different activity against different micro-organisms; the yeast - *C. Albicans*, is the most sensitive to the silver-loaded Co/PES fabrics. Also, there is no clear dose dependant antimicrobial activity but the quantity of bonded silver ions, in all cases, is enough to develop a desirable antimicrobial activity in the silver-loaded Co/PES fabrics.

Table 1. Antimicrobial activity of the silver-loaded Co/PES fabrics

Sample	DBD exposure time, s	Ag^+ sorption, mmol/g	Width of the inhibition zone + suppression zone mm		
			S. aureus	*E. coli*	*C. albicans*
Co/PES	0	0	0	0	0
Co/PES + Ag	0	0.045	0.7	0.7	0.7
Co/PES + Ag*	30	0.073	1.0	0.5	2.0
Co/PES + Ag*	60	0.073	1.0	0.7	2.5
Co/PES + Ag*	120	0.072	1.3	1.0	2.7
Co/PES + Ag**	120	0.135	1.0 + 2.5	2.5 + 2.5	2.5

*Ag^+ sorption immediately after the DBD treatment; ** Ag^+ sorption after 7 days of aging

CONCLUSIONS

The antimicrobial Co/PES fabrics prepared by dielectric barrier discharge mediated silver deposition show the antimicrobial activity against tested pathogens: *S. aureus, E. coli,* and *C. albicans* under *in vitro* conditions. The obtained results confirm the practicability of the plasma process in the activation of the fabric surface and furthermore show that with some delays in the next step, *i.e.* silver ion sorption, we can get the increase in the amount of the sorbed silver ions; the maximum sorption capacity of modified Co/PES fabrics was 0.135 mmol of Ag^+ ions per gram of a fabric.

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