Introduction

Nonwoven fabrics may be manufactured inexpensively so that they can be used in disposable products that are discarded after only one or a few uses. Polypropylene (PP) nonwoven fabrics, selected for this study, are used in disposable absorbent articles, such as diapers, feminine care products and wipes, as well as hospital healthcare textiles, such as beddings, curtains, uniforms, towels, etc. Nonwoven in such applications is exposed to microbial contamination and all negative effects that cause (i.e. deterioration, odours, health risk) /1/. Among numerous ways by which antimicrobial properties can be accomplished in textiles, plasma-based treatments combined with deposition of different antimicrobial agents 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 /2,3/.

In this paper we present a comparative study on functionalization of PP nonwovens by different plasma treatments: volume dielectric barrier discharge - DBD and diffuse coplanar surface barrier discharge - DCSBD followed by silver ions and gold nanoparticles (AuNPs) deposition onto the plasma activated fabric surface from aqueous solution. A series of the DBD and DCSBD fabric treatments were done in order to determine the most suitable experimental conditions for the plasma activation of the fabric surface.

Experimental

The tested fabric was commercial spun-bonded PP nonwoven fabric with a fabric weight of 50 g/m² and a thickness of 271±22 µm.

In this work, two different plasma sources, volume dielectric barrier discharge and diffuse coplanar surface barrier discharge, both working in air at ambient
temperature and pressure, were used for PP nonwoven activation, i.e. generation of active groups on its surface, in order to achieve better deposition of Ag ions and AuNPs. **DBD treatment:** The discharge is generated in a parallel plane discharge configuration consisting of two aluminum electrodes (8.0 x 8.0 cm), both covered by a 0.65 mm thick Al₂O₃ ceramics layer (10.5 x 10.5 cm). The bottom electrode is covered with spherical zeolite granules, in one layer, to avoid problems with humidity and to maintain a homogeneous discharge (for detailed description see literature /3/). The PP nonwoven sample strips (15 x 80 mm) were treated for 15, 30, 60, and 120 seconds using plug-in energy density of 1.8, 3.6, 7.2 and 14.4 J/cm², respectively. **DSCBD treatment:** Plasma treatment was implemented by the DCSBD technology on a laboratory scale. Detailed description of DCSBD electrode design, consisting of 19 pairs of silver strip electrodes, is given in literature /4/. A DCSBD discharge with a surface power density of 2.0 W/cm² was ignited, and after stabilisation of the discharge current, the PP nonwoven sample was brought into contact with the DCSBD electrode system surface using a sample carrier. Treatment time, from 3 to 24 seconds (6 – 48 J/cm²), was measured as the contact time of the sample with the plasma.

SEM, AFM, ATR-FTIR, water absorption, and Ag ions/AuNPs uptake were used to assess the surface changes on the PP nonwovens due to the plasma treatment, as well as durability of achieved treatment effects. Antimicrobial activity of Ag ions and AuNPs loaded PP nonwovens against different pathogens: *Staphylococcus aureus, Escherichia coli*, as well as durability of obtained effects, were evaluated *in vitro.*

**Results and discussions**

Plasma treatment induced a significant change in the chemical composition of the surface of PP nonwoven (the characteristic bands of oxygen containing functionalities were identified in the ATR-FTIR spectra), data not shown. The formation of new carbonyl and carboxyl groups led to an increase in hydrophilicity of PP nonwoven as was confirmed by increase in water absorption. Figure 1 shows the effects of plasma treatment time on the water absorption by DBD and DCSBD plasma activated PP nonwoven fabrics. For the DBD and DCSBD treated fabrics, it is evident from these data that the water absorption i.e. hydrophilicity, gradually increased with increasing treatment time. In the case of DCSBD modified nonwoven a good hydrophilization effect was obtained after exposure of 12 s (24 J/cm²), and with prolonged plasma treatment the water absorption did not change significantly. In the case of the volume DBD modified nonwoven a good hydrophilization effect was obtained only after exposure of 15 s (1.8 J/cm²). With prolonged plasma treatment the
water absorption changes significantly (water absorption up to 270 %).

**Fig. 1.** The effect of treatment time on the water absorption by DCSBD and DBD plasma activated PP nonwoven fabrics.

**Fig. 2.** SEM image of 120 seconds plasma treated PP by DBD and with deposited AuNPs.

New functionalities introduced to the fabric surface, and subsequently increased hydrophilicity induced by plasma treatment enhanced deposition of AuNPs and Ag ions onto PP fibers, which was confirmed by SEM (Fig.2.) and ICP-OES analysis (Figs.3 and 4). The content of Au on the DBD treated PP fibers was almost 4 times higher compared to untreated PP fibers, whereas on the DCSBD treated PP fibers the content was almost 3 times higher than on untreated PP fibers (Fig.3). In the case of Ag deposition (Fig. 4), the content of Ag ions on the DBD and the DCSBD treated PP was almost 4.5 times and 5 times higher than on untreated PP, respectively.

**Fig. 3.** Quantity of Au on the AuNPs loaded DBD and DCSBD treated PP nonwovens.

**Fig. 4.** Quantity of silver ions absorbed onto PP nonwoven after plasma pretreatment by DBD and DCSBD.

Results of antimicrobial tests show that incorporation of gold nanoparticles and silver ions in PP nonwovens leads to the generation of antimicrobial
materials having activity against a broad spectrum of microbes (Gram-negative bacteria strains – *E. coli*, Gram-positive bacteria strains – *S. aureus*, and yeast – *C. albicans*). There is no clear dose dependant antimicrobial activity but the quantity of bonded silver ions, in all cases, is enough to develop desirable antimicrobial activity in the silver-loaded PP nonwovens. Stability of achieved antibacterial activity regard to rinsing was investigated and obtained results indicate that the obtained antibacterial activity of silver and gold-loaded PP nonwovens was stable in regard to rinsing.

**Conclusions**

The potential of modified volume dielectric barrier discharge and diffuse coplanar surface barrier discharge in air, at atmospheric pressure, for treatments PP nonwoven fabrics to improve their wettability and AuNPs and silver deposition was demonstrated. The PP nonwovens prepared by DBD and DCSBD mediated silver and gold nanoparticles deposition show antimicrobial activity against tested pathogens: *S. aureus*, *E. coli*, and *C. albicans* under *in vitro* conditions.

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**References**