PREPARING ANTIBACTERIAL TEXTILES BY SONOCHEMICAL METHODS

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Introduction

The growing interest in textile materials with antimicrobial properties has stimulated an extensive search for new technologies for the modification of wool fibers and the production of safety yarns [1]. Different types of antimicrobial treatments have been studied for the protection of wool products from damage caused by pathogenic microorganisms. Among these treatments, there is the coating of wool with resinbonded copper-8-quinolinolate, chlorinated phenol and its derivatives, sodium dichloroisocyanurate, quaternary ammonium-compounds, metal ions, and organic tin compounds in finishing processes. A biotemplate redox technique has been employed for the deposition of silver nanoclusters on another type of natural fiber—silk fibroin fiber. We demonstrated the deposition of small silver nanoparticles on woolen fabrics by the coating of neat fibers with silver nanoparticles via ultrasound irradiation. We suggest that this product can serve as an antimicrobial fabric. The process is performed in a one-step sonochemical procedure with slurry-containing wool fibers, silver nitrate, and ammonia, in an aqueous medium. The produced silver-coated wool fabrics maintained the high flexibility and elasticity typical of wool. The studies of the silver-coated wool fibers by physical and chemical methods have demonstrated the presence of highly dispersed XRD amorphous silver nanoparticles (~5 nm) incorporated into the natural wool. The development of new clothing products based on the immobilization of nanophased materials on textile fibers has recently been of increasing interest to both the academic and the industrial sectors. Nanostructured silver deposited on textile substrates can be used to make smart functional textiles, which have great potential for applications ranging from antibacterial materials to conductive shields and electronic sensors.

Results and Discussion

We offer a new coating technique, sonochemistry, which has been used already to coat nanoparticles on ceramics , polymers, glass , and in the current presentation on various kinds of textiles. We introduce in the sonication cell the solid substrate and the precursors for a well-known sonochemical reaction leading to known nanoparticles. The microjets formed after the collapse of the bubble throw the just-formed nanoparticles at the surface of the substrate at such a high speed that they strongly adhere to the surface either via physical or chemical interaction, depending on the nature of the substrate. If instead of forming the nanoparticles we purchase them and use ultrasonic radiation just for throwing, a good adherence is still obtained, but the amount of nanopaticles found on the surface is smaller by a factor of 3-4.

We have applied the sonochemical method for the deposition of silver nanoparticles onto the surface of different fabrics (nylon, polyester, wool, and cotton). The advantage of the process is that this is a simple, efficient, one-step synthesis. The process produces a uniform coating of silver nanoparticles on surfaces with different functional end groups. Physical and chemical analysis has shown that nanocrystalline pure silver, 80 nm in size, is finely dispersed on the fabric's surface without any significant damage to the structure of the yarn (Fig. 1). The coating is stable on the fabric for at least 20 washing cycles in hot (40 ^{o}C) water.

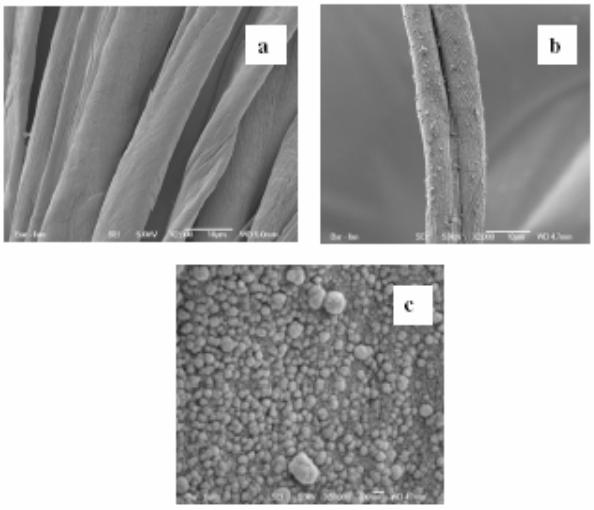

Figure 1. (a) HR-SEM images of pristine fibers, (b) fabrics coated with Ag nanoparticles at a low magnification, (c) fabrics coated with Ag nanoparticles at a high magnification

In light of new demands for environmental protection, the use of nanosilver-containing products is strictly limited by the FDA. It is based on the determination that silver ions can't be easy removed from living organisms and the human body. Thus, we have directed our efforts towards the replacement of silver in

antibacterial textiles with other antibacterial agents, such as ZnO and MgO. These oxides are generally regarded as materials safe for human beings and animals, and are used extensively in the formulation of personal care products. Using a simple, one-step ultrasound assisted procedure, we succeeded in synthesizing ZnO nanoparticles and depositing them on cotton sheets and bandages. The ZnO cotton composite demonstrated an excellent antibactericidal activity against gram-positive and gram-negative microorganisms. A similar method was also used for the deposition of MgO and CuO nanoparticles on cotton bandages.

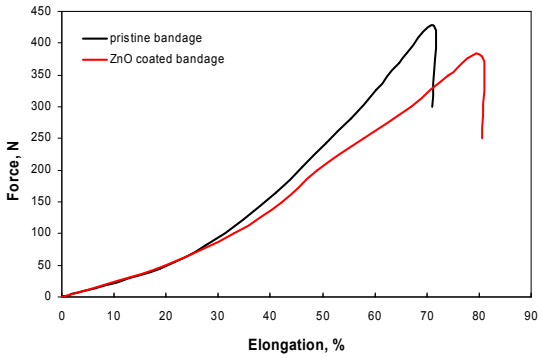

Figure 2. Mechanical properties of the cotton bandage before and after the deposition of ZnO nanoparticles.

In Figure 2 we present the results of these mechanical studies.

One of the factors influencing the commercial exploitation of the antibacterial textiles is the release of the nanoparticles into the surrounding environment. Although the main hazard arises from the release of the ZnO nanoparticles into water upon laundering, we have also examined the release of the Zn^{+2} ions. While the leaching of the Zn^{+2} ions is governed by the K_{sp} of ZnO, and Zn^{+2} is considered as an environmentally safe ion, a much more important and serious issue is the leaching of ZnO nanoparticles. In light of a recent paper [i] that found that silver nanoparticles of 10 to 500 nm in diameter leach from sock textile, we have conducted special experiments in an attempt to find the amount of leached ZnO nanoparticles. The methods we used for the leaching examination were DLS and TEM. The DLS and TEM studies did not reveal the presence of any nanoparticles in the leaching solution. That means that the sonochemically deposited ZnO nanoparticles are strongly anchored to the textile substrate. We have conducted a detailed study of the mechanism by which the ZnO nanoparticles kill the bacteria. Using ESR studies we have established that OH radicals are the cause for the biocidal activity. These radicals are formed as a results of defects in the ZnO crystal.

Table 1

Duration of treatment						
	1h			2h		
Sample	CFU ml^{-1}	N/N_0	% reduction in viability	CFU ml^{-1}	N/N_0	% reduction in viability
			E. coli			
Clean fabric	$1{,}02 \times 10^7$	0,98	2,4	$1{,}34 \times 10^7$	1,28	-28,23
No fabric	$1{,}17 \times 10^7$	1,14	-28,57	$1{,}23 \times 10^7$	1,35	-35,16
0.75% ZnO (sample 5)	$1{,}71 \times 10^4$	$1{,}58 \times 10^{-3}$	99,84	0	$\sim 9 \times 10^{-8}$	100
			Staph. aureus			
Clean fabric	$0{,}7 \times 10^7$	0,71	20,46	$0{,}99 \times 10^7$	1,125	-12,5
No fabric	$0{,}98 \times 10^7$	1,1	-10,11	$0{,}67 \times 10^7$	0,75	24,72
0.75% ZnO (sample 5)	$3{,}9 \times 10^6$	$3{,}36 \times 10^{-1}$	66,4	$7{,}6 \times 10^3$	$6{,}55 \times 10^{-4}$	99,93

In Table 1 we present the antibacterial properties of a 5X5 cm piece of cotton bandages coated with ZnO NP against *E.coli* and *Staphylococcus aureus*. The tensile mechanical properties of the ZnO coated-cotton impregnated fabric were studied. The tensile force was found to be ~11% less than that of the pristine bandage.

References

[1]. Sun, Y. Sun, G. , Durable and regenerable antimicrobial textile materials prepared by a continuous grafting process *J. Appl. Polym. Sci.* **84** (2002) 1592.