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Synthesis and Physicomechanical Studies of Nano ZnO Coated Textile Fabrics

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In the current study cotton fabric was in situ loaded with zinc oxide nanoparticles (ZnONPs). Urea was used as a dispersion medium to transform zinc acetate salt into ZnONPs within the matrix of the cotton fabric. These cotton fabrics were characterized before and after loading of ZnONPs using Differential thermal analysis (DTA), Fourier-transform infrared spectroscopy (FTIR), Scanning electron microspore (SEM) coupled with Energy dispersive x-rays (EDX), tensile strength and air permeability in order to determine the effect of the in situ loaded ZnONPs cotton fabrics on the thermal behavior, chemical integrity, microstructure, mechanical properties and air permeability (%) properties of the cotton fabrics. The obtained results revealed that presence of in situ loaded ZnONPs has a slight effect on the thermal behavior of the cotton fabrics. Also, presence of in situ loaded ZnONPs was confirmed by FTIR and SEM coupled with EDX techniques in form of dispersed aggregates within the cotton matrix. The physical properties (breaking load up to 50Kg and percentage elongation of 18%) of the in situ loaded ZnONPs were found to be dependent on the concentration of the ZnONPs. This treated cotton fabrics are recommended for biomedical applications.

Keywords: In situ; Physical properties; ZnO NPs; Cotton; Biomedical applications.

Introduction

Owing to the advances usage of cotton fabrics it's considered nowadays as one of the best alternatives for biomedical applications based on their low cost, tunability and synthesis simplicity [1]. Several antibacterial finishing agents were widely used in modifying of cotton fabrics to tolerate their final application especially in the field of biomedical applications. In addition, this could be done also to modify the deterioration properties of cotton fabrics [2-4]. When several conditions are combined together including moisture, oxygen, appropriate temperature and nutrients cotton fabrics are considered to be the perfect environment for microbial growth [5]. To provide better condition

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of health and good environmental circumstances for humane race, increasing demands for antibacterial clothes are recorded. Therefore, plenty of technical cotton fabrics are increasingly developed for different needs like specialized wound dressings, bandages, masks, and surgical gowns with antibacterial properties. Varity of methods and ingredients were involved in the industry of such cotton fabrics based on their potential application [6].

It is worthy highlight that, the structure of material is easily manipulated to give desired properties in their nano-scale. Great motivation is directed for the utilization of nanotechnology in the production of cotton fabrics that has expanded quickly in the last few decades. This is could be attributed to the fact that cotton fabrics possess ideal matrix for infiltration of nanomaterials. Ideal diameters for nanomaterials for the biomadical applications fall in the range o 1-100nm [7]. In comparison with the coatings made of organic materials routinely utilized in the treatment of cotton fabrics, inorganic materials demonstrate no critical debasement and are incredibly steady and the oxides are categorized as non-lethal materials [8]. Zinc oxide is non-toxic and that is the reason it is utilized in beauty care products, for example, sun creams. For the recently referenced reasons, zinc oxide is apparently ideal for the arranging of extraordinarily specialized cotton fabrics [9].

There are numerous reports on the extensive antibacterial effect of ZnO nanostructures [10-13]. The benefit of utilizing this inorganic oxide as an antimicrobial agent is that it contains mineral components naturally exist in the body and shows powerful effect. The use of ZnO nanoparticles to cotton fabrics has been the object of a few investigations aiming for delivering antibacterial textile materials. In situ precipitation of metal oxide on cotton fabrics or fibers is a promising strategy that outcome in a progressively uniform nanoparticles infiltration through the cotton fabric matrix [14-15]. In this technique, the metal oxide is adsorbed onto fabric surfaces by electrostatic or Van der Waals powers and with the presence of urea, it diminishes metal oxide into nanoparticles.

In the current research, the potential utilization of ZnO nanostructures for surface treatment of cotton textures has been researched. ZnO nanostructures were in situ combined on the outside of cotton fabric through productive wet chemical precipitation method (simple cost-effective method). The conducted technique offers points of interest as the treated cotton fabrics well represent antibacterial textiles potential for various medical applications.

Materials and Method

Medium weight- fine cotton fabrics (Honeycomb weave, Ends/inch: 46, Picks/inch: 43) were subjected to the ZnONPs treatment. Zinc acetate anhydrous (Mw=183.50 g/mol) was purchased from El Nasr Pharmaceutical Chemicals CO., Egypt. Urea (Mw=60.06 g/mol) was acquired from Sigma Aldrich Co., Germany. Ammonia hydroxide solution 25% (Mw=35.05 g/mol) was delivered by Alahram Laboratory Chemicals Co., Egypt.

Preparation of nanoparticles treated cotton fabrics

ZnONPs were prepared using simple chemical precipitation. Practically, 15.49 and 22.13g (7 and 10%) of zinc acetate were dissolved in de ionized water using magnetic stirrer at room temperature. Afterword, urea powder was added to the zinc acetate solution and stirring was continued till clear solution was obtained. This was followed by submersion of several pieces of cotton fabrics in the achieved mixture. The cotton fabrics pieces were cut with different dimensions according to required analysis (5x10 cm for tensile test and 10x10 for air permeability test). After 30 min of submersion with continued stirring, the pH of the solution were changed to 9.5 using ammonia hydroxide solution and the reaction temperature was elevated to 90^{o}C for one hour. The cotton fabrics pieces were then collected from the above mixture, rinsed with deionized water for three times and left to dry in the room temperature for one hour. Finally, the pieces of the cotton fabrics were then dried for 10 min at 190 ^{o}C and kept in desiccator for further investigations.

Characterization of ZnONP treated cotton fabrics

The treated cotton fabrics were investigated before and after treatment by means of Differential thermal analysis (DTA), Fourier Transmittance Infrared (FTIR), Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-rays (EDX), tensile strength and air permeability in order to determine the effect of the in situ loaded ZnONPs on the thermal behavior, chemical integrity, microstructure, mechanical properties and air permeability (%).

Results and discussion

The used method in the current study is considered as an eco-friendly method, due to the absence of organic solvents or any other toxic agents that may have deformation effect on the textile or has a lethal effect on the user.

Thermal behavior

The effect of the in situ loaded ZnONPs on the thermal behavior of the cotton fabrics was evaluated by DSC/TGA and their thermograms are represented in Fig. 1. In general, two narrow endothermic peaks were observed for the cotton fabrics at 133 and 335°C a combined with weight loss resulted from the cotton fabrics decomposition increased by presence of ZnONPs. The first peak is attributed to the humidity and water evaporation and the second one was assigned to the thermal decomposition of the cotton fabrics. Slight shift was detected for these two peaks upon the inclusion of ZnONPs (133 to 123 and 335 to 375). This remarkable shift is suggesting that the thermal stability of the cotton fabrics was enhanced in the presence of ZNoNPs. While, the remaining thermal decomposition was observed after 600 °C is assigned to Zn- containing ash. Similar results were obtained for textile treated with ZnONPs [16]

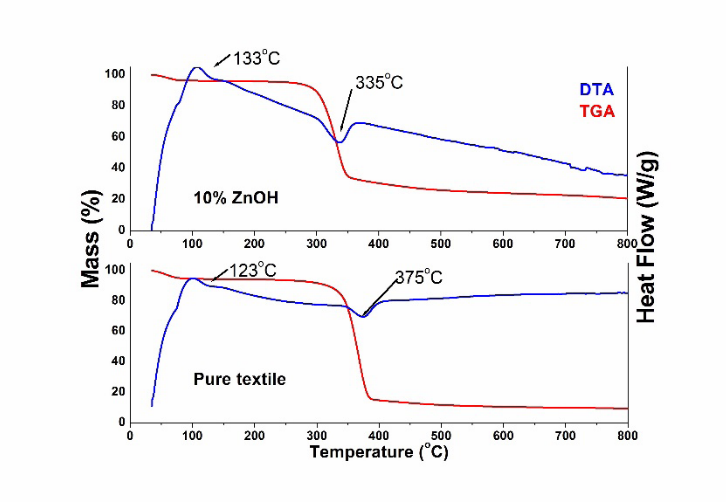


Fig. 1 DSC/TGA thermograms demonstrate cotton fabrics before and after loading of ZnONPs.

Chemical interaction by FTIR

In order to investigate the chemical interaction that takes place during the treatment of cotton fabrics with ZnONPs, FTIR measurements were conducted. In Fig. 2 the FTIR spectra for the ZnONPs loaded cotton fabrics were represented in comparison with the pure ones. It could be noticed that the chemical interaction was remarkably recognised at three regions. The first region is in the wavenumber range of 3750- 3000 cm^{-1} that is assigned to OH group, where the intensity of this band increased with the increase of ZnO concentration. This result was consistent with early reported research work [1]. The second region was allocated in the wavenumber range of 1200-1050 cm^{-1} that corresponds to the presence of –C–O–C– group, the intensity of this band increased with 10% ZnOH content. This was in the same line with results of previous study [17]. The third region was observed in the wavenumber range of 600-500 cm^{-1} corresponding to the stretching mode of Zn-O functional group. This confirms the inclusion of ZnONPs within the matrix of the cotton fabrics [18]. In addition, presence of other bands was confirmed for treated and non-treated cotton fabrics. These bands were detected in the wavenumber range of 1750- 1250 cm^{-1} that corresponds to vibration of OH group and that attributed to amine group [19]. Also band recorded on the wavenumber range of 3000-2750 cm^{-1} attributed to ($-CH_2-$) functional group [20].

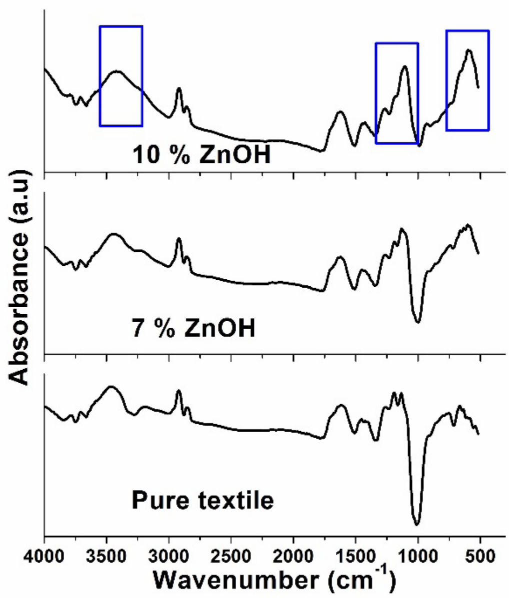


Fig. 2 FTIR of the ZnONPs loaded cotton fabric with reference to the pure textile.

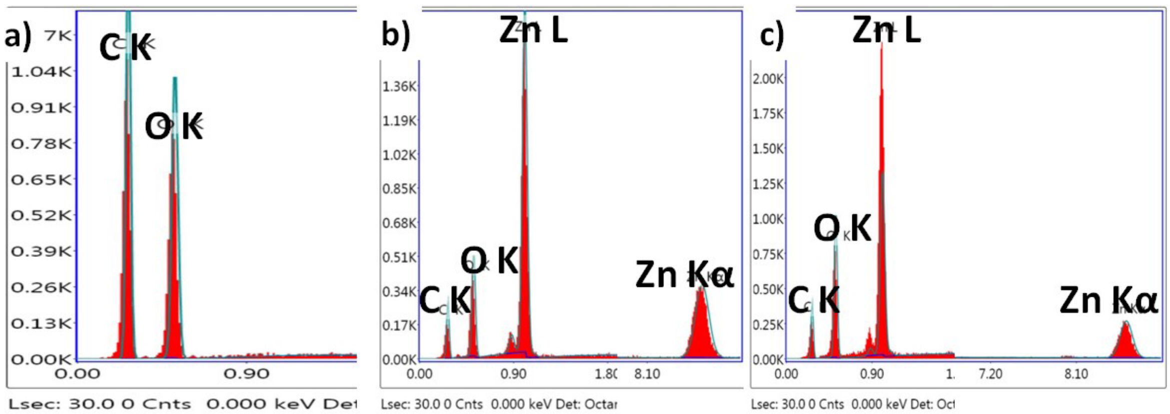
Microstructure of the treated cotton fabrics

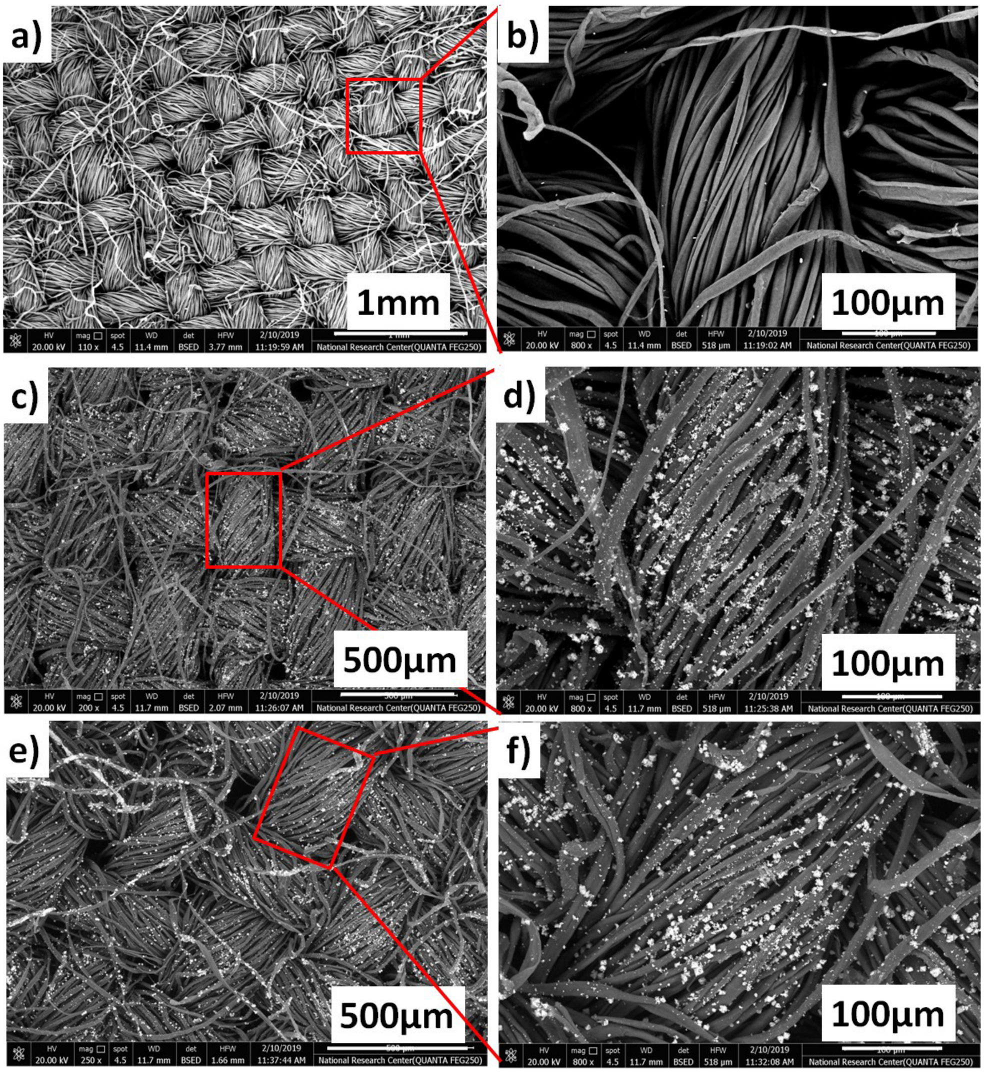
The microstructure of the treated cotton fabrics were investigated with reference to the pure textile using SEM. Fig 3 demonstrates the microstructure of the cotton fabric before and after loading of ZnONPs with different concentrations. Pure textile exhibited smooth surface without any observation for solid particles. In the other side treated cotton fabrics showed solid white precipitation distributed homogenously within the matrix of the cotton fabrics. These white precipitates were increased with increase of the ZnONPs concentration. This result confirms the inclusion of ZnONPs in the cotton fabrics in impressive way and thus validated the used method for the aimed purpose. This result was consistent and comparable with early reported studies [21-23].

Fig. 3 SEM images of a) and b) pure cotton fabric; c) and d) treated with 7% $^{W}/_{V}$ ZnONPs ; e) and f) treated with 10% $^{W}/_{V}$ ZnONPs with different magnifications.

Elemental analysis for the treated cotton fabrics

In order to confirm the inclusion of ZnONPs in the matrix of the cotton fabrics EDX analysis were conducted. Fig. 4 represents the elemental analysis conducted using EDX for the treated and non-treated fabrics. Pure cotton fabric only affirmed the presence of tow elements carbon and oxygen, thus related to polymer backbone of the cotton. On the other hand, the presence of Zn element was confirmed for the treated cotton fabrics with ZnONPs. This result was in agreement with several reported studies [24-27].





Fig, 4 EDX results of a) pure cotton fabric, b) treated with 7% $^{W}/_{V}$ ZnONPs and c) treated with 10% $^{W}/_{V}$ ZnONPs.

Tensile strength and air permeability of the ZnONPs treated cotton fabrics

The influence of the ZnONPs on the cotton fabrics physical properties such as tensile strength and air permeability were evaluated using tensile strength Instron® Automated Materials Testing System and air permeability tester KES-F8-AP1 designed by Kato Tech. Co. Ltd., Japan. The estimated parameters for these characterization techniques are summarized in Table 1. From Table 1 it is clear that inclusion of ZnONPs within the matrix of the cotton fabrics has remarkable influence on the tensile strength and air permeability properties when compared to pure cotton fabric. In details, presence of ZnONPs has increased the tensile strength and the elongation percentage of the cotton fabric and this was more pronounced at higher concentration of ZnONPs. However, the air permeability of the cotton fabrics decreased with the increase of ZnONPs content (see table 1). Air permeability is an important factor in the performance of textile materials used to provide an indication of the breathability of coated fabrics. Although the notable decrease of the air permeability in this study it is still in the acceptable ranges for treated textiles in previous research work [24, 28, and 29-31].

Table 1 Tensile strength and air permeability parameters

Sample	Tensile strength		Air permeability ($cm^3/cm^2/sec$)
	Breaking load (kg)	Elongation (%)	
Pure textile	40.00	13.00	99.84
7% ZnOH	48.60	16.65	30.25
10% ZnOH	49.30	17.68	18.16

Conclusion

In the current study cotton fabrics were treated successfully with ZnONPs using simple chemical precipitation technique. The inclusion of ZnONPs into the matrix of the cotton fabrics and its uniform distribution were confirmed by means of FTIR, SEM coupled with EDX. The physical properties of the treated cotton fabrics were controlled by the concentration of the loaded ZnONPs. The above achievements support the implementation of the current treated cotton fabrics in several biomedical applications such as self cleaning clothes or antimicrobial patches.

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