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Study on the Antimicrobial Efficacy of Fabrics Finished with Nano Zinc Oxide Particles

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Abstract

In this paper, knitted fabrics were finished with Zinc Oxide nano particles of 30 nm & 90 nm size. To make knitted fabrics, 100% cotton and 67/33 Polyester/Cotton ring spun yarns made with varying twist factors were selected. Knitted fabrics were finished with nano ZnO particles by Exhaust-dry-cure method and the samples were evaluated for anti-microbial efficacy. Test results indicate that in general, anti-microbial efficacy of samples increases with increase in yarn twist and decrease in ZnO particle size. Polyester cotton blend samples show better anti-microbial efficacy than cotton samples.

Keywords: Anti-microbial efficacy • Knitted fabrics • Ring spun • Particle size • Zinc oxide nano particles

Introduction

The application of nano particles to textile materials aimed at producing finished fabrics with a variety of functional performances. Nano finishes are processes in which Nano particles of metallic origin are synthesized and then applied onto textile substrate to get the desired functional properties, to suit various end use requirements [1,2]. Nano particles have many advantages over the conventional finishing agents such as high durability, good wash fastness, etc. due to their smaller size and increased surface area. The application of Nano finishes enable ultra-strong, durable, and specific function oriented fabrics to be effectively produced for numerous applications such as military, industrial, medical, domestic, apparel, house hold furnishing and many more [2]. Nano finishes have been effectively applied to cotton, wool, silk and polyester fabrics. Antibacterial finishes have been applied on cotton, wool, silk and polyester fabrics as well, with the twin objective of protecting the wearer and fabric too. In the case of Nano finishing with synthetic textile materials, the aspects to be considered have been odor elimination, antistatic, and antibacterial properties. Nano particle dispersions have also been used in photonic applications besides textile wet processing. Zinc oxide (ZnO) Nano particles have been used for antimicrobial properties and protection against UV radiation [3,4]. Zinc oxide has been the most preferred among other types of Nano particles owing to their superiority with regard to photo-catalytic, electrical, electronics, optical, dermatological and anti-bacterial properties [5-7]. Moreover, it has three unique characteristics, namely, semi conductivity, piezoelectricity, and bio safety compatibility. These special characteristics make zinc oxide the most prospective Nano material for future textile research. The effect of coating of Nano ZnO particles on Polyester fabrics indicates that the antibacterial efficacy and washing stability of coated polyester samples depends on the composition of the coating solution. It has been found that Particles of ZnO in the range of 50 nm-300 nm demonstrate better results with regard to antibacterial efficacy after different washing cycles whereas nanoparticles with a size of 10 nm shows improved optical appearance. ZnO concentration up to 20µg ZnO/cm^2 is found to exhibit suitable antibacterial effect and requires cyto-compatibility [8]. The influence of various chemical auxiliaries used in finishing operations, the process temperature, pH and the treatment duration on the anti-bacterial efficacy of samples of man-made fibers containing ZnO in blends with cotton shows that the influence of those factors on anti-bacterial efficacy is less significant. Anti-bacterial properties of surface modified polyamide 6 (PA), polyethylene terephthalate (PET) and polypropylene (PP) textiles using zinc oxide reveals that the amount and structure of antibacterial layer on samples is dependent on roughness and wettability of textile surfaces and rougher and more hydrophilic is the material, the more ZnO were deposited [9]. The biggest amount of ZnO microrods was present on PA, then PET and the least on PP. Crystallite sizes and strain values were highest for PET, PA and least for PP samples. Samples show significant bactericidal activity particularly against Gram-negative bacteria [10]. The antibacterial effect on cotton fabrics modified with nanosized zinc oxide by in situ method using zinc acetate dihydrate as precursors and sodium hydroxide, with and without starch as a capping agent shows that the size and morphology of Nano sized zinc oxide on cotton fabric in presence and absence of starch reveals that more hydrophobic character of treated cotton as compared with blank, will have high potential applications in various fields [11]. UV reflectivity and antibacterial activity of cotton samples loaded with hexagonal zinc oxide sheets indicates that the samples show high UV reflectivity, better antibacterial activity against *Escherichia coli* and *Staphylococcus aureus* organisms and also better Infrared barrier results. Properties of ZnO coated polyester fabric treated with sodium hydroxide demonstrated that increasing of zinc oxide Nano particles concentration increases bending length, water adsorption time, antibacterial and self-cleaning effect. Pre-alkaline-treated fabric had more zinc oxide nano particles; therefore more self-cleaning and bactericidal effect than simultaneous alkali treatment samples [12]. Fabrics are more susceptible to microbial growth especially natural fibers like cotton, when moisture, oxygen and suitable temperature exist than the fabrics made from synthetics. In this work, Nano ZnO particles of 30 nm & 90 nm size have been applied on knitted fabrics produced from 100% cotton and 67/33 polyester/cotton yarns of 34 Ne count. The yarns produced with varying Twist factors (TF) were used, to study the effect of twist factor on the antimicrobial efficacy (AME) of fabrics. The Nano particles were characterized by evaluating particle size and shape by using X-ray diffractometry and SEM microscopy. The ZnO Nano particles are then applied on to the fabrics using binder, by exhaust-dry-cure technique and the samples have been evaluated for antibacterial efficacy by standard test methods.

Materials and Methods

100% cotton yarns and Polyester/Cotton (67/33) blend yarns made from Ring spinning system with different twist factors were used for this study. The yarn samples were tested for basic parameters and the technical specifications are given in Table 1.

The yarns were made into single jersey plain knitted fabrics with constant loop length of 0.26 cm. The machine details are given in Table 2.

The knitted fabrics were scoured and bleached using Caustic Soda

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Table 1. Yarn specifications.

Parameters	100% cotton yarn			67/33 P/C yarn		
	Twist Factor 1	Twist Factor 2	Twist Factor 3	Twist Factor 1	Twist Factor 2	Twist Factor 3
Count (Ne)	29.52	29.37	29.47	30.48	30.37	30.03
Count CV%	1.99	1.20	1.45	1.29	1.08	1.52
Twist Factor	3.32	3.66	3.94	3.32	3.66	3.94
TPI	17.80	19.38	21.14	18.10	19.86	21.46
CSP	2178	2390	2558	4150	4033	4049
U%	13.04	12.67	12.65	10.03	9.92	10.23
Hairiness Index	7.75	7.01	6.56	5.81	5.34	5

Table 2. Knitting machine particulars.

Type	Single Jersey
Make	Pailung
No. of Feeders	72
Dia (Inches)	24
Gauge	24
No. of needles	1800

Table 3. Percentage reduction in bacterial count after 24 hours.

Fibre Type	TF	Samples Finished with 30 nm ZnO		Samples Finished with 90 nm ZnO	
		S. aureus	*E. coli*	*S. aureus*	*E. coli*
100% Cotton	3.32	74	80	68	72
	3.66	77	88	78	62
	3.94	88	74	88	42
67/33 P/C	3.32	84	82	69	74
	3.66	86	88	80	72
	3.94	92	92	91	62

(2 gpl), Hydrogen Peroxide (2.5 gpl) and detergent (0.7 gpl), at 98°C temperature for 30 minutes. The fabrics were then rinsed, neutralized with Acetic acid (0.8 gpl) and washed again.

Finishing of fabric samples with ZnO Nano particles

The fabric samples were finished with Zinc Oxide Nano particles of 30 nm & 90 nm by Exhaust-dry- cure method. Samples of 30 x 30 cm size were cut and immersed in the solution prepared with 2% ZnO of 30 nm size and 1% Acrylic binder at MLR of 1:20, for 15 minutes. Then the samples were taken out, squeezed in 2 bowl padding mangle at 60% expression to remove excess liquor and air dried. The samples were cured at 140°C for 2 minutes and rinsed with 2 gpl Sodium Lauryl Sulphate to remove unfixed particles. Then the samples were rinsed several times in water to remove soap solution. Similarly samples were also finished with 90 nm ZnO particles, for comparison.

Testing of Anti-Microbial efficacy (AME) of samples

The anti-microbial efficacy of treated and untreated (control) samples were evaluated quantitatively as per AATCC 100 standard against *Staphylococcus aureus* and *Escherichia coli*. The anti-microbial efficacy (AME) was determined by comparing bacterial concentration of treated samples with that of untreated sample, expressed as percentage reduction in 24 hours.

Results and Discussions

Anti-Microbial efficacy of treated samples

The finished sample0073 were tested for Anti-Microbial Efficacy as per AATCC 100 standard. Table 3 shows the percentage reduction of bacterial count of treated samples for Gram Positive & Gram negative organisms after 24 hours of contact time. Bacterial reduction was calculated based on the comparison of bacterial Count in treated samples and untreated samples.

From the results shown in Table 3, it is observed that the anti-microbial efficacy of treated samples against gram positive organism (*S. aureus*) increases with increase in yarn twist factor (TF) both 30 nm and 90 nm ZnO finished samples. In case of bacterial reduction of gram negative organism (*E. coli*), increase in yarn TF leads to increase in anti-microbial efficacy for 30 nm ZnO treated samples but it decreases for the samples treated with 90 nm ZnO Nano particles.

Influence of Nano particle size on the AME

To study the influence of Nano particle size on the AME of ZnO treated samples, percentage reduction in bacterial count of 30 nm ZnO treated samples was compared with 90 nm ZnO treated samples and expressed as percentage change in AME.

Percentage change in AME is the ratio between difference in AME of treated samples with 90 nm and 30 nm ZnO particles to the AME of treated samples with 90 nm ZnO, expressed as percentage. Percentage change in AME=(AME of samples treated with 30 nm ZnO-AME of sample treated with 90 nm ZnO) x 100/AME of sample treated with 90 nm ZnO.

From the Table 4, it is revealed that the ZnO particle size has an effect on antimicrobial efficacy of samples against Gram-negative organism (*E. coli*) i.e. smaller the ZnO particle size higher is the AME. The decrease in ZnO particle size leads to maximum of 48% increase in AME of samples. But, not much increase in AME is observed against *S. aureus* organism irrespective of yarn TF and fibre type. The AME against *S. aureus* is almost same for 30 nm and 90 nm ZnO finished samples in most samples except for samples with TM of 3.32. This is due to the difference in susceptibility of Gram-positive and Gram-negative bacteria against ZnO nano particles.

Gram-negative bacteria seemed to be more resistant to ZnO nanoparticles than gram-positive bacteria due to the differences in cell wall structure, cell physiology, metabolism or degree of contact. Gram-positive bacteria have one cytoplasmic membrane with multilayer of peptidoglycan polymer and a thicker cell wall (20 nm-80 nm), whereas gram-negative bacteria wall is composed of two cell membranes, an outer membrane, and a plasma membrane with a thin layer of peptidoglycan with a thickness of 7 nm-8 nm. Nano particle size within such ranges can readily pass through the peptidoglycan and hence are highly susceptible to damage.

Another reason for low AME against *E. coli* of treated samples is that at lower concentrations, ZnO nanoparticles may not be toxic for various tested microorganisms and *E. coli* can metabolize Zn2+ as an oligoelement [13-15]. It is concluded that, due to higher susceptibility of gram positive organism to ZnO, higher bacterial reduction percentage is observed against *S. aureus* both in 30 nm and 90 nm ZnO finishing. Irrespective of particle size, ZnO particles are able to destroy gram positive organism. Whereas Gram-negative organism show higher resistance against 90 nm ZnO particles leading to low bacterial reduction and when the particle size decreases, ZnO particle are able to pass through peptidoglycan of organism which results in higher bacterial reduction. This is the reason for the remarkable increase in AME against *E. coli* owing to the decrease in ZnO particle size from 90 nm to 30 nm. Change in bacterial reduction against *E. coli* is also enhanced by the yarn twist factor. It is observed that change in bacterial reduction is higher at higher yarn TM.

Samples treated with 30 nm ZnO nano particles show higher bacterial reduction percentage than those samples treated with 90 nm ZnO nano particles due to the fact that 30 nm sized nano particles have relatively higher surface area to volume than 90 nm particles. The antibacterial efficacy increases with decreasing particle size which is due to enhanced bioactivity of smaller particles probably attributed to the higher surface area to volume ratio.

Influence of yarn TM on the AME

From the Table 5 it is observed that antimicrobial efficacy against Gram-positive organism (*S. aureus*) increases with increase in TF, for both 30 nm and 90 nm ZnO finished samples of 100% cotton and 67/33 P/C samples. But against Gram-negative organism (*E. coli*), AME generally decreases with increase in yarn TF, except for 67/33 P/C samples finished with 30 nm ZnO.

The increase in AME of samples against *S. aureus* due to increase in yarn TM may be attributed to the influence of fabric constructional parameters. Fabric weight and thickness increases owing to the increase in yarn TM. In order to study the association between yarn TM and fabric constructional parameters such as weight, thickness& TF, correlation coefficient values are calculated and shown in Table 5.

From the Table 5, it is evident that increase in yarn TM positively influences fabric weight, thickness and TF. It is seen that the most significant influence of yarn TM is on the fabric weight. Hence due to increase in weight of the fabric samples due to increase in yarn TM, more Nano particles maybe bound onto fabric surface per given area, which might be the reason for their increased antimicrobial efficacy.

Influence of fibre type on the AME

In order to study the influence of fibre type on the AME of ZnO treated samples, percentage reduction in bacterial count of fabrics made from 100% cotton and 67/33 P/C yarns are compared and the percentage change in AME is calculated.

Positive values in the Table 6, indicate that microbial reduction for 67/33 P/C samples are higher than 100% cotton samples at all the three twist level. It is due to the fact that cotton fibres naturally are more susceptible to microbial growth than polyester fibre. This agrees with earlier findings that P/C samples show better bacterial reduction than the 100% cotton samples because of better bacterial resistance of polyester component [16-24]. Higher difference in AME is observed against for *S. aureus* in samples finished with 30 nm ZnO and against *E. coli* in samples finished with 30 nm ZnO particles.

Table 4. Percentage change in AME of treated samples (30 nm ZnO against 90 nm ZnO).

Fibre Type	TF	Percentage change in antimicrobial efficacy	
		S. aureus	*E. coli*
100% Cotton	3.32	8.82	11.11
	3.66	-1.28	41.94
	3.94	0	76.19
67/33 P/C	3.32	21.74	10.81
	3.66	7.5	22.22
	3.94	1.1	48.39

Table 5. Correlation coefficient values between yarn TM and fabric parameters.

Finished with ZnO particle size of	Correlation coefficient values		
	Weight	Thickness	TF
30 nm	0.99	0.99	0.99
90 nm	0.99	0.89	0.99

Table 6. Percentage change in bacterial reduction of 67/33 P/C samples compared with 100% cotton samples.

TF	Percentage change in antimicrobial reduction of samples			
	30 nm ZnO		90 nm ZnO	
	S. aureus	*E. coli*	*S. aureus*	*E. coli*
3.32	13.51	2.50	1.47	2.78
3.66	11.69	0	2.56	16.13
3.94	4.60	24.32	3.41	47.62

Conclusions

It is observed that samples finished with 30 nm ZnO particles show higher bacterial reduction percentage than the samples finished with 90 nm ZnO particles against both Gram-positive and Gram-negative organisms. This is due to the fact that 30 nm sized Nano particles have relatively higher surface area to volume than 90 nm particles. This agrees with earlier findings that smaller particle size have larger surface area and thus increased contact with microorganisms leading to improved bactericidal and fungicidal effectiveness.

It is evident that increase in yarn TM leads to increase in AME in all samples. This is due to the increase in fabric weight owing to the increase in yarn TM which results in increased antimicrobial efficacy. Increase in yarn TM and increase fabric weight leads to more Nano particle adhesion onto the fabric surface. More ZnO Nano particle on the fabric surface leads to better antimicrobial activity. But against *E. coli*, different trend is observed that AME decreases with increase in TM for the samples finished with 90 nm ZnO.

Samples made from 67/33 P/C yarn show better AME than the samples made from 100% cotton yarn which is due to the fact that polyester blend samples are less susceptible to microbial growth than 100% cotton samples.

References

1. Gokarneshan Narayanan, Gopalakrishnan Palanippan and Balraj Jeyanthi. "Influence of nanofinishes on the antimicrobial properties of fabrics." *Int Sch Res Notices* 2012 (2012).
2. Gokarneshan Narayanan and Gopalakrishnan Palanippan. “Influence of Nano particles on the functional properties of textile materials.” *Int J Basic App Chem Sci* (2012): 8-24.
3. Pan ZW. “Nano belts of semi conducting devices.” *Science* (2003): 4-10.
4. Vigneshwaran Nadanathangam, Sampath Kumar, Kathe Varadarajan, and Virendra Prasad. "Functional finishing of cotton fabrics using zinc oxide-soluble starch nanocomposites." *Nanotechnology* 20 (2006): 50-87.
5. Yadav AVP. “Functional finishing in cotton fabrics using zinc oxide Nano particles.” *Bulletin of material science* (2006): 641-645.
6. Parthasarathy VTG. “Synthesis and characterization of titanium dioxide Nano particles and their applications to textiles for microbe resistance.” *J Text Appar Technol Manag* (2009): 1-8.
7. Parthasarathy VTG. “Synthesis and characterization of zinc oxide Nano particles and its applications on fabrics for microbe resistance defence clothing." *Int J Pharm Pharm Sci* (2011): 392-398.
8. Rode Claudia, Michael Zieger, Ralf Wyrwa, and Susanne Thein, et al. "Antibacterial zinc oxide nanoparticle coating of polyester fabrics." *J Tex Sci Technol* (2015): 65-70.
9. Popescu ARM. “The behavior in finishing of textile materials of manmade fibres containing ZnO in blends with cotton.” *Ind Textila* (2018): 212-218.
10. MartaFiedot Tobota “Deposition of Zinc oxide on different polymer textiles and their antibacterial properties.” *Materials* (2018): 707-710.
11. Mahmoudi ATN. “In situ production and deposition of Nano sized zinc oxide on cotton fabric.” *Iran J Chem Chem Eng* (2020).
12. Shrin NMM. “Zinc oxide nano particles coating on polyester fabric functionalized through alkali treatment.” *J Ind Text* (2016).
13. Thangamani and Gopalakrishnan Palanippan. “Finishing of knitted fabrics using ZnO Nano particles for anti micobial and ultraviolet protection.” *J Text Assoc* (2016): 243-247.

14. Baglioni PDL. “Preparation of nano and micro particle of group II and transition metal oxides and hydroxide and their uses in the ceramic.” *Tex paper ind* (2003): 82-742.

15. Chattopadhyay DPPB. “Improvement in physical and dyeing properties of natural fibres through pre-treatment with silver Nano particles.” *Indian J Fibre Text* (2009): 368-373.

16. Chellamani KP. “Breathability of surgical gowns treated with nano finishes.” (2011): 45-51.

17. El Molla. “Nanotechnology to improve colouration and anti-microbial properties of silk fabrics.” *Indian J Fibre Text* (2011): 266-271.

18. Kathirvelu SLD. “Study of stain eliminating textiles using ZnO Nano particle.” *J Text I* (2010): 520-526.

19. Kathirvelu SLD. “UV protection finishing of textiles using ZnO Nano particles.” *Indian J Fibre Text* (2009): 267-273.

20. LHJ. Bacteriostatus and skin innoxiousness of Nano size colliods on fabrics. *Text Res J* (2005): 551-556.

21. Martyias ZBA. “Anti-microbial properties of silver finished textiles.” *Fibres Text East Eur* (2008): 101-107.

22. Ruimin. “Fabrication of ZnO @ cotton fabric with anti-bacterial and radiation barrier properties using an economical and environmentally friendly method.” *J Ind Text* (2016).

23. Sawney. “Modern Applications of Nanotechnology in Textiles.” *Text Res J* (2008): 731-739.

24. Tang. “Surface modification of zinc oxide nano particle by PMMA and its dispersion in aqueous system.” *Appl Surf Sci* (2006): 5227-5232.

25. Tang Erjun, Guoxiang Cheng and Xiaolu Ma. "Preparation of nano-ZnO/ PMMA composite particles via grafting of the copolymer onto the surface of zinc oxide nanoparticles." *Powder Technol* 161(2006): 209-214.

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