Research Article

Effect of Silver Nanoparticles on Wool Fibre

R. Perumalraj

Department of Fashion Technology, Bannari Amman Institute of Technology, Sathyamangalam 638 401, India

Correspondence should be addressed to R. Perumalraj, raj134722002@gmail.com

Received 4 October 2012; Accepted 7 November 2012

Academic Editors: F. Banat and A. Ragauskas

Copyright © 2012 R. Perumalraj. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Silver nanocolloids have been synthesized by chemical reduction of silver salt solution, characterized by SEM usage of nanoparticles. Silver nanocolloids are treated with wool fibres and dyed wool fibres (direct and acid dyes). The physical properties, colour strength, and fastness properties have been studied for dyed wool fibres and ordinary wool fibres. It is observed that the fibres with nanotreated fibres have better strength than untreated wool fibres. It is also observed that there is considerable improvement in colour strength and colour fastness of silver nanocolloids-treated wool fibres (dyed).

1. Introduction

During the past two decades, the small-particle research has become quite popular in various fields of chemistry and physics. The small particles, now we call nanostructured materials, are having interesting properties. Metallic nanoparticles represent a class of materials that are increasingly receiving attention as important starting points for the generation of micro- and nanostructures. These particles are under active research because they possess interesting physical properties differing considerably from that of the bulk phase. It has small sizes and high surface/volume ratio. Silver nanoparticles have received considerable attention due to their attractive physical and chemical properties.

Metallic silver colloids were first prepared more than a century ago. Ag nanoparticles can be synthesized using various methods, such as chemical, electrochemical, γ -radiation, photochemical, and laser ablation. The most popular preparation of Ag colloids is chemical reduction of silver salts by sodium borohydride or sodium citrate. This preparation is simple, but the great care must be exercised to make stable and reproducible colloids. The purity of water and reagents and cleanliness of the glassware are critical parameters. Solution temperature, concentrations of the metal salt and reducing agent, and reaction time influence particle size. Controlling size and shape of metal nanoparticles remains a challenge. The size-induced properties of nanoparticles

enable the development of new applications or the addition of flexibility to existing systems, in many areas, such as catalysis, optics, microelectronics, and textiles. Antimicrobial effect of silver nanoparticles on textiles has already been shown by various researchers [1–3].

Wool fiber, known for its lightness, softness, warmth, and smoothness, is known as a natural clothing material. Because wool is mainly composed of keratin, the outermost part of the fiber is the cuticle cell, of which the surface is a fatty layer of 18-methyl Eicosanoic acid covalently bound to the protein layer of the wool cuticle via a thioester linkage. Because of the presence of this fatty layer, the surface of wool is hydrophobic. Therefore, the water absorption and sweat venting properties of wool fiber are not very good, which affects the wearing comfort of wool textiles [4–9].

Wool was treated with inorganic and polymer-based nanoparticles. The diffusion of nanoparticles into wool appears to be dependent on electrostatic interactions. In particular, it is optimized at low pH in which there are very few anionic groups on the wool fiber. The nanoparticles also need to have sufficient charge to maintain their stability as dispersion. The findings support the view that the cell membrane complex and other low sulphur regions are the main route of entry for both molecular and macromolecular treatment chemicals. The use of this technique to treat wool may lead to new coloration effects and other functions such as antimicrobial action [4–14].

FIGURE 1: Surface images of wool fiber having 100 ppm silver particles with sulfur nano-silver colloid; (a) 5,000 magnifications and (b) 30,000 magnifications.

2. Preparation of Nano-Ag Colloid

The 100 mL solution of 1×10^{-3} M AgSO_4 , kept in the specially designed reaction chamber, was slowly reduced by dropwise addition of very dilute chilled solution of sodium borohydride in a nitrogen atmosphere. During the process of reaction the solution mixture was stirred vigorously. When the colour of the solution turned to light yellow, 5 mL of 1% trisodium citrate was added drop by drop with vigorous stirring. Distilled water was used for preparing the solutions of all the chemicals.

Silver nanoparticles were applied to the wool samples by dipping them in the dispersion for 10 min and then padded on an automatic padding mangle machine using 2-dip-2-nip padding sequence at 70% expression. The padded substrates were air dried and finally cured at 120°C for 20 min in a preheated curing oven.

These nanoparticles have been applied to the wool fibres by using the padding technique and manifested the improved microbial resistance as measured through the soil burial test. The dyeing behaviour of the silver nano particle treated fibres with direct dyes and acid dyes has been also studied. The higher color strength K/S values are obtained when the Ag nano is anchored in the fibre matrix, that is, when the fibre is pretreated and dyed with direct dyes and acid dyes. Improved colour strength with good wash and light fastness is also obtained after the treatment of fibres with nanocolloids.

3. Results and Discussions

3.1. Effect of Silver Nano on Physical Property. It is observed from Table 1 that the tenacity of silver nano particles treated wool fibres has better strength than the untreated wool fibre, and the introduction of nanosilver particles into the structure of the fibre causes an improvement in the load

TABLE 1: Tenacity of treated and untreated samples.

Sample no.	Tenacity (gram/denier) Untreated sample	Tenacity (gram/denier) Treated sample
1	1.33	1.99
2	1.12	1.84
3	1.32	1.90
4	1.08	1.69
5	0.90	1.52

bearing capacity of the fibre. The nanosilver particles because of their small size can enter in between the molecules and perhaps act as filler or crosslinking agent which also contributes to the load sharing phenomenon during load application to the material. Unlike chemical crosslinking which causes an improvement in crease recovery angle at the cost of imparting some rigidity in the material to an extent depending on the extent of crosslinking, the incorporation of nanosilver particles remains quite gentle in this regard.

Wool fibres are subjected to severe mechanical actions like padding and relaxation in chemical processing, the reason for crimp loss in wool fibers. The crimp% of wool fibers was noted in different stages. The loss of crimp and crimp recovery of wool fibres were examined by crimp shrinkage tester. It is observed from the Table 2 that the crimp % of Ag nano treated fibres are lower than the untreated wool fibres.

It is also observed from Table 3 the considerable reduction in moisture regain for nano silver particle treated wool fibres. Wool is a very hygroscopic fibre picking up and losing moisture as the atmospheric conditions change. At 65% relative humidity, wool will hold 14%-15% of its own weight in moisture. It will absorb more than 30% moisture before it begins to feel wet. There is a large variation in moisture and,

TABLE 2: Crimp% of treated and untreated samples.

Sample no.	Crimp in raw wool	Crimp in dyed wool	Crimp loss (%)	Crimp in Ag nano colloidal treated and Dyed Wool	Crimp loss (%)
1	33	29	12.1%	27	18
2	30	26	13.3%	24	20
3	31	28	12.9%	26	16
		Avg	12.7%		18

TABLE 3: Moisture regain% of treated and untreated samples.

Sample no.	Moisture regain% of untreated wool			Moisture regain% treated wool		
	Before	After	M.R (%)	Before	After	M.R (%)
1	1.39	1.21	14.8	0.301	0.272	10.67
2	0.733	0.634	13.5	0.41	0.368	11.4
3	0.573	0.497	15.2	0.382	0.345	10.72

TABLE 4: Color strength K/S values of treated and untreated samples.

Sample no.	Color strength K/S values dyed with acid dyed		Color strength K/S values dyed with direct dyes	
	Test 1	Test 2	Test 1	Test 2
1	9.32	9.38	6.82	6.85
2	10.7	10.67	8.57	8.58
3	9.62	9.65	7.26	7.23

similarly, large variation in the weight of a consignment. This may be due to the fact that silver nano particle deposition over the surface of the wool fibres.

3.2. Effect of Ag Nano Treatment on Dyeing

3.2.1. Color Strength Testing of Treated and Untreated Fibers.

The Ag nano particles were treated with direct dyed and acid dyed wool fibres, and the color strength values have been studied with Ag nano particles treated wool fibres and untreated wool fibres. It is observed from Table 4 that the color strength K/S values of the nanosilver pretreated samples do not have much difference than those of the corresponding untreated wool samples. The silver nano treated direct dyed wool fibres have better K/S values than untreated wool fibres. The very suitable acid dyes have higher K/S values. The higher Color Strength K/S values (Table 4) of nanotreated samples indicate that the presence of nanometal particles increases the dye affinity towards the material. The silver nanoparticles in the fabric thus act as mordant. The negatively charged dye anions get attracted towards the fibre probably due to the polarity developed in the metal particles by induction which results in better bonding between the dye and the fibre. The better coupling of the dye and the fibre is also reflected in the improvement in the colour fastness properties. Thus, silver nano pretreatment not only improves the colour strength but also improves the colour fastness which is a major drawback of most direct dyes.

3.3. Surface Analysis by SEM. The surface of treated wool fabrics was observed by SEM. In Figure 1, SEM images show

wool scales that were treated with 100 ppm of silver contents. The nano-silver particles bigger than 4.2 nm of particles in SNSE solution were observed in Figure 1(b). The agglomerated particles may be attributable to the thermomigration of the nanosized silvers happening during curing process.

3.4. Antibacterial Property. Nanosized silver particles in colloidal solution had excellent antibacterial effect on all specimens against gram-positive and gram-negative bacteria. Data shows the antibacterial effect of nanosized silver colloidal solution on processed fabric. In the result, the bacterial reduction of all specimens was very excellent against *E. coli*. In this study, the application of silver nano particles as an antimicrobial agent was investigated by growing *E. coli* on agar plates. When nano particles were present on agar plates, they could completely inhibit the bacterial growth. However, inhibition depends upon concentration of silver nano particles.

It is clear that treated bacteria also show significant changes in and damages to membranes. The fabrics padded through 30 mL/L silver colloidal solution also had better activity than the samples treated with 20 mL/L solution at 22°C.

The results obtained from antimicrobial test show that with silver concentration at the 10 mL/L and temperature at 22°C the antimicrobial activity increases with increases in curing time. The higher bacterial inhibition was also obtained at 30 mL/L and 22°C with the increase in curing time. The bacterial inhibition at 20°C is much less when compared to 22°C and 24°C with increase in curing time.

4. Conclusion

Silver nano colloids have been synthesized by chemical reduction of silver salt solution, characterized by SEM image of nano particles.

- (i) The samples treated with silver nanoparticles show better tensile strength and drying time than normal samples.
- (ii) Nano Ag treatment enhances the color strength of dyed wool fibres (Direct dye and Acid dye) and also improves the fastness towards light and washing.
- (iii) Ag nano treatment to wool improves the resistance to microbial attack.

References

- [1] K. Patel, S. Kapoor, D. P. Dave, and T. Mukherjee, "Synthesis of nanosized silver colloids by microwave dielectric heating," *Journal of Chemical Sciences*, vol. 117, no. 1, pp. 53–60, 2005.
- [2] L. Razafimahefa, S. Chlebicki, I. Vroman, and E. Devaux, "Effect of nanoclays on the dyeability of polypropylene nanocomposite fibres," *Coloration Technology*, vol. 124, no. 2, pp. 86–91, 2008.
- [3] M. Radetic, V. Ilic, V. Vodnik et al., "Multifunctional properties of polyester fabrics modified by corona discharge/air RF plasma and colloidal TiO₂ nanoparticles," *Polymers for Advanced Technologies*, vol. 19, no. 12, pp. 1816–1821, 2008.
- [4] J. Cegarra, P. Puente, and J. Gacén, "Influence of wool bleaching with hydrogen peroxide on dyeing with CI Acid Blue 80," *Coloration Technology*, vol. 121, no. 1, pp. 21–24, 2005.
- [5] J. A. Maclaren and B. Milligan, *Wool Science: The Chemical Reactivity of the Fibre*, vol. 122, Science Press, Marrickville, Australia; Coloration Technology, Millington, Tenn, USA, 1981.
- [6] J. Cegarra, J. Gacén, and M. Caro, "Optimization of the conventional bleaching of wool with hydrogen peroxide," *The Journal of the Society of Dyers and Colourists*, vol. 94, pp. 85–90, 1978.
- [7] J. Gacén and D. Cayuela, "Comparison of wool bleaching with hydrogen peroxide in alkaline and acidic media," *Journal of the Society of Dyers and Colourists*, vol. 116, no. 1, pp. 13–15, 2000.
- [8] X. Liu, C. J. Hurren, L. J. Wang, and X. G. Wang, "Effects of bleaching and dyeing on the quality of alpaca tops and yarns," *Fibers and Polymers*, vol. 5, no. 2, pp. 128–133, 2004.
- [9] J. R. Barone, W. F. Schmidt, and N. T. Gregoire, "Extrusion of feather keratin," *Journal of Applied Polymer Science*, vol. 100, no. 2, pp. 1432–1442, 2006.
- [10] J. R. Barone, W. F. Schmidt, and C. F. E. Liebner, "Thermally processed keratin films," *Journal of Applied Polymer Science*, vol. 97, no. 4, pp. 1644–1651, 2005.
- [11] K. Katoh, M. Shibayama, T. Tanabe, and K. Yamauchi, "Preparation and properties of keratin-poly(vinyl alcohol) blend fiber," *Journal of Applied Polymer Science*, vol. 91, no. 2, pp. 756–762, 2004.
- [12] S. Novak, S. Kobe, and P. McGuinness, "The effect of chemically bonded organic surface layers on the behaviour of fine powders," *Powder Technology*, vol. 139, no. 2, pp. 140–147, 2004.
- [13] W. Xu, W. Cui, W. Li, and W. Guo, "Development and characterizations of super-fine wool powder," *Powder Technology*, vol. 140, no. 1-2, pp. 136–140, 2004.
- [14] X. Wang, W. Xu, and G. Ke, "Preparation and dyeing of super-fine down-powder/viscose blend film," *Fibers and Polymers*, vol. 7, no. 3, pp. 250–254, 2006.