SILVER NANOPARTICLE DISPERSIONS FOR ANTIMICROBIAL FINISHING OF TEXTILES

by

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Submitted

in fulfilment of the requirements of the degree of

Doctor of Philosophy

to the

Indian Institute of Technology Delhi

April 2013

Dedicated to my parents, my family, friends and to all my teachers

CERTIFICATE

This is to certify that the thesis titled '**Silver Nanoparticle Dispersions for Antimicrobial Finishing of Textiles**', being submitted by **Ms. Sangita Paul** to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by her. She has worked under our guidance and supervision and fulfilled the requirements for submission of the thesis which has attained the standard required for a Ph.D. degree of this institute.

The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

It is a moment of great pleasure and contentment for me to express my sense of gratitude and sincere appreciation to my supervisors Prof. Manjeet Jassal and Prof. Ashwini K. Agrawal, Department of Textile Technology, IIT Delhi, for providing constant guidance, encouragement, careful attention and constructive criticism during the tenure of this PhD. I will always be indebted to them for their invaluable suggestions and untiring attention, which they have shown right from the beginning till the successful completion of this endeavour. They have inspired me in many ways throughout my study academically as well as personally. It has indeed been a privilege to be associated with them for so many years during which I tried to learn a lot from them.

I also express my thanks to Prof. Kushal Sen, Dr. Deepti Gupta and Prof. Veena Choudhury for their valuable suggestions. I would also like to acknowledge the financial support provided by the Department of Science and Technology (DST), Govt. of India and Resil Chemicals Pvt Ltd, Bangalore towards the scholarship and research grant for carrying out the thesis work and international patent application.

I would also take this opportunity to thank Dr. Chhatar Singh (SEM Lab), Mr. D.C Sharma (SEM Lab), Mr. Ashok Kumar, Mr. V. A. Passi, Mr. V. K. Kala, Mr. Vinod, A. K. Sehgal, Mr Raj Kumar and all other supporting staff members of the department for their sincere help.

I am also thankful to my friends and lab mates especially Mr. Dhirendra Singh, Ms.Ratyakshi Nain, Ms Deepika Gupta, Ms Kamlesh, Ms Kiran Yadav, Mr Syamal Maiti, Mr Kartick Samanta for their support and encouragement. The constant encouragement of those whom I love the most, my parents, brother, husband, daughter, sister-in-law and family have motivated me to complete this work. Lastly but not the least, I express my sincere thanks to all those who have helped me directly or indirectly during the course of my research work.

Sangita Paul

ABSTRACT

Silver is a known antimicrobial agent since ancient times. Silver nanoparticles (AgNPs) show efficient antimicrobial property due to their large surface area, which provides better contact with microorganisms. The surface activity and colour (optical properties) of the AgNPs is dependent on their size, shape, size distribution and chemical–physical environment. The antibacterial activity of AgNPs was also recognized to be related to their shape and size. For effective antimicrobial activity (i.e. > 80%) on textile substrates, finishes based on silver nanoparticles (usually spherical) are applied on textiles/substrates in concentrations from 5 ppm to 350 ppm and even as high as 1000 ppm. This imparts high yellowness index and patchy appearance to the treated fabric which is aesthetically undesirable. Further, most of these silver nanoparticles (AgNPs) are available in dispersion form, which are stable for a limited period. This limits commercial application of antimicrobial silver based finish. Moreover, the reproducibility of the colour, particle size and stability of the dispersion is an issue. Further, AgNP treated fabrics are either not durable to washing or they show only acceptable wash durability to mild washing conditions.

In this study, AgNP dispersions were synthesized via chemical reduction method in an aqueous medium in the presence of shape directing agents. The effect of concentration of reducing agent and temperature of synthesis was investigated and the two parameters were found to have profound effect on the shape and size of AgNPs. Tuning of borohydride concentration and synthesis temperature in a narrow range could yield anisotropic AgNPs of peak value of average size ~3 nm, which is the smallest reported till date. Similarly, isotropic AgNPs of peak value of average size ~2.6 nm could also be obtained. The AgNP dispersions obtained under the study were extremely stable to different pH conditions, accelerated gravity and high temperature, which gave the dispersions a shelf life of over 2 years under normal

room conditions.AgNP dispersions also had good compatibility with different auxiliaries used in finishing formulations.

Antimicrobial activity (AM) of AgNPs is usually attributed to their shape and size. As-prepared anisotropic AgNPs, having comparatively larger size, showed higher AM activity (MBC value 0.09-0.1 ppm) than the spherical AgNPs of smaller size (MBC value 0.2-0.25 ppm) indicating higher activity of anisotropic shapes. However, detailed investigations revealed that the AM activity is greatly influenced by the clustering behaviour of AgNPs, which in turn is affected by the shape of the AgNPs. Use of suitable surfactants in appropriate concentrations could enhance the AM activities of both the AgNP dispersions in such a way that AM activity could be directly related to the available surface area of the AgNPs in dispersion. The MBC values of 0.055 ppm and 0.025 ppm could be obtained for well dispersed anisotropic and isotropic AgNPs, respectively. These values are the lowest ever reported in the literature for the two types of AgNP dispersions. The results showed that contrary to the earlier belief, the different AM activities shown by AgNPs of different shapes are influenced more by their clustering behaviour rather than their shapes.

The as-synthesized AgNPs were applied to different textile substrates, such as cotton, A. vera/cotton union fabrics, nylon and wool, and fixed by curing them at different temperatures. It was found that AgNPs could adhere well when fixed at temperatures higher than 120 °C. The AM activity could be retained to a great extent even after 20 home laundary washes. The result has significance due to the fact that these particles could be fixed without the use of any binder.

The application of AgNP dispersions at concentrations as low as 0.1 ppm could result in high AM activity in the range of 98-100%.

The anisotropic AgNPs having optical appearance of blue colour, when applied to textile substrate, could result in optical brightening of the substrates in addition to providing high AM activity. Also, due to the high AM activity of these dispersions, isotropic AgNPs could be appiled at very low concentrations to yield antimicrobial fabrics with high aesthetics and low yellowness index.

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