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DEVELOPMENT OF ANTIBACTERIAL NANO TEXTILES

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ABSTRACT

The article comprehensively reviews some significant trends in the development of antimicrobial textiles by application of nano metal oxide particles. The green synthesis of silver nanoparticles (AgNPs) was carried out by using Zanthoxylum rhesta plant's fruit extract for the first time. The green synthesis and in situ deposition of silver nano particles (AgNPs) on cellulose fibers in cotton was carried out by wet and sono chemical methods. The AgNPs and AgNPs deposited cotton fabrics were fully characterized. The crystallite size of particles obtained by both methods was around 37 nm and the hydrodynamic diameters were in the range of 69 to 184nm and 75 to 111nm. Functional cotton with high and durable antibacterial activity by in situ formation of Ag nanoparticles (NPs) onto cotton fabric derived from phytic acid-Ag complex. The route can be divided into two simple steps, adsorption of silver ions onto cellulose matrix with phytic acid as a capture agent and subsequent reduction of Agþ to Ag NPs by sodium borohydride. The successful deposition of Ag NPs on cotton fabric was verified by SEM, EDS and XPS. The developed textile materials have been tested against gram negative bacteria.

KEYWORDS: Silver nano particles, Green synthesis, Anti microbial activity, Cotton, Textile, Chemical synthesis.

1. INTRODUCTION

The development of 'green chemistry' approach for the synthesis of nano materials has replaced many toxic reagents from their synthesis.[1-3] There are huge number of reports in the literature about green synthesis of various nanoparticles in particular of silver nanoparticles.[4-7] These reports include the synthesis of AgNPs using extracts of various

parts of the plants from different categories. The phytochemicals present in the extracts act as reducing agents for the formation of AgNPs. The AgNPs are well-known for their excellent antimicrobial properties.[8,9]

Natural textiles, such as cotton and silk, have been widely used in human's life because of their outstanding properties, like regeneration, softness and affinity to skin.[10] Currently, to cater to the need of market and improve human living standards, considerable efforts have been devoted to functionalization of textiles, endowing them with antimicrobial, self-cleaning, UV-blocking, and flame-retardant properties.[11-24] For cotton, which is seen as the most extensively used and abundant natural cellulose material, the antimicrobial finishing is one of the most important modifications, since the growth of microbes on cotton fabrics influenced not only their properties, but also the health of human beings. Unfortunately, warm and moist environments and nutrients attachment are usually suitable for microbe growth and reproduction on cotton fabric surface.[25]

2 Methods of preparation of antimicrobial nano textiles

The antimicrobial activity of silver or AgNPs is known to be effective against 650 types of bacteria.[26,27] Hence AgNPs have been used in various antimicrobial products and formulations.[28,29] Recently, there is an increased interest to exploit the antimicrobial properties of AgNPs by their deposition on various fabrics to prepare nanotextiles with antimicrobial properties.[30-32] Textiles and clothing materials are good media for the growth of microorganisms.[33-35] The microbes grow on all types of textiles and use them as a nutrient hence there is a need to develop textiles with antimicrobial properties that prevent the growth of microbes on them. The deposition of AgNPs on textiles is one of the main approach to prepare antimicrobial textiles.[36] The deposition can be done by different techniques such as pad and dry cure, pulsed laser ablation, sol-gel, layer-by-layer coating and sono chemical techniques etc.[37-41] The synthesis of nanoparticles can also be carried out directly in the presence of the fabric to achieve synthesis and simultaneous deposition of the particles on the fabrics. The sono chemical synthesis and deposition technique is frequently used for this purpose due to its proven efficiency. The sono chemical process involves the formation of AgNPs under ultrasound irradiation and their in situ deposition on cotton fabrics in a single step.[42,43] However, many of the in situ deposition methods/processes reported use chemical reagents as reducing agents for the synthesis of AgNPs which increases the cost of the overall process. Additionally, the chemical reducing and stabilizing agents used in the synthesis may

remain attached on the textiles. There are a number of separate reports about green synthesis of AgNPs and on the preparation of AgNPs-deposited cotton fabrics by various techniques.[44] The combination of green synthesis and in situ deposition of AgNPs on cotton fabrics is interesting as the deposition is achieved in a single step.[45]

Based on this motivation, in the present work, we report the green synthesis of AgNPs and their in situ deposition on cotton fabrics. For this purpose, Zanthoxylum rhesta fruit extract was used as a reducing agent for the synthesis of AgNPs. Zanthoxylum rhesta (Tirphal in local language) is a plant found in abundance in the Western Ghat region of Maharashtra, India. To the best of our knowledge, this is the first report on the use of Zanthoxylum rhesta fruit extract for the synthesis of AgNPs and also of the deposition of AgNPs on cotton fabrics to prepare nano textile with antimicrobial properties without the use of any binder, stabilizer using wet chemical and sonochemical methods. In this work, first the optimization of the synthesis procedures of AgNPs by wet chemical and sono chemical methods was done followed by repeating the optimized synthesis in the presence of cotton fabrics. The synthesized AgNPs and AgNPs-deposited cotton fabrics were fully characterized. Finally, the antimicrobial activity of the AgNPs-deposited cotton fabrics was tested against the strains of gram positive and gram negative bacteria. The current research is undertaken with a view to devise a plausible route for in situ synthesis and deposition of AgNPs on cotton fabrics without damaging and losing their intrinsic properties. This work presents a significant advancement in the field of preparation of nanotextiles with excellent antimicrobial activity by a smart combination of green synthesis of AgNPs combined with in situ deposition approach.

In conclusion, green synthesis of AgNPs was successfully carried out by using Zanthoxylum rhesta fruit extract by wet chemical and sonochemical methods. The synthesis and simultaneous deposition of the nanoparticles on cotton fabrics was achieved by both the methods.[46] The deposition of AgNPs imparted antimicrobial properties to the fabrics. The active phytochemicals present in extract were responsible for the reduction of Agþ to Ag_ to obtain the particles. The results of characterization by UV-visible, XRD, ATR-FTIR, DLS, and SEM techniques revealed the formation of stable monodisperse AgNPs and their deposition on the cotton fabrics. The AgNPs prepared by both methods were finely incorporated and deposited onto the cotton fabrics. The sono chemical technique was found to be comparatively bit more effective to disperse the particles and because of that a uniform

deposition was achieved. The AgNPs-deposited cotton fabrics showed excellent antimicrobial activity against gram negative and gram positive bacterial strains. The advantage of the methods developed is that it is a single step deposition, without use of any binder, surfactants or any toxic chemicals. As there are no any harmful organic impurities deposited on the fabrics the AgNPs-deposited fabrics possess potential applications in areas such as wound dressing, bed lining, medicinal bandages, medical, food equipment, and packaging materials.

3 Nano silver treated cotton fabric for durable antimicrobial property

Up to now, various antimicrobial agents are applied, such as quaternary ammonium compounds, inorganic nanoparticles (NPs), triclosan, chitosan and its derivatives, to tackle this weakness of cotton.[47-53] The loading of inorganic nanoparticles, including silver, copper and some metallic oxides, has recently become a popular way to produce antimicrobial cotton fabrics.[54-56] Among all the NPs applied, Ag NPs have the advantages of low toxicity and excellent antimicrobial activities against both Gram-positive and Gram-negative bacteria.[57-59] To sum up, three methods are used to prepare Ag NPs-coated textiles, including spinning fibers with synthesized polymer-nanoparticle composites, ex situ, and in situ synthesis of nanoparticles onto the fabric surfaces.[60-63] Because of the excellent stability and uniform distribution on textile as well as the eco-friendly process, in situ synthesis of Ag NPs on fabrics hence aroused attention, in which the silver ions are firstly absorbed onto the fabrics and subsequently reduced into Ag NPs.[64] And some other works presented in situ deposition of Ag NPs into cotton fibers directly in alkaline environment and high temperature, which used cellulosic groups as reducing and stabilizing agent. These methods, however, suffer from obvious limitation of low density of loaded Ag NPs due to the limited Agþ-binding sites on the cotton fibers, meanwhile, the bonding between the hydroxyl groups and Ag NPs in the fibers is always weak that leads to poor washing durability. In order to solve the above problems, Rehan et al. modified cotton surface by cationization and partial carboxymethylation, and achieved formation of Ag NPs on the modified samples using trisodium citrate as both the reducer and stabilizing agent.[65] Zhang et al. used amino-terminated hyper-branched polymer (HBP-NH2) as reducer and stabilizer to prepare amino functional Ag NPs, which were then grafted onto the pre-oxidized cotton fabrics to obtain excellent antibacterial property (Zhang, Chen, Zang, Chen, & Lin, 2013).[66] However, these approaches may be not suitable for practical application due to their long reaction time and chemical consuming. Moreover, some used polymers are toxic and difficult to degradation.

Therefore, the development of a simple and green approach for efficient formation of Ag NPs on textiles is urgent.

In this study, phytic acid has been used (myo-inositol 1,2,3,4,5,6-hexakisphosphate, PA) as a capture and stabilizing agent to prepare Ag NPs-coated cotton fabrics through in situ synthesis strategy. The silver ions were first adsorbed onto cellulose matrix in the presence of PA and subsequently reduced to Ag NPs by sodium borohydride. As a green and natural composition of plant, PA was widely found in nuts, pollens, fruits, legumes, oil seeds and vegetables.[67] Its six phosphate groups can provide enough binding sites for silver ions, which enhance the bonding of Agþ on cotton surface; meanwhile, the presence of PA could increase steric hindrance and electrostatic repulsion among the nanoparticles, resulting in good distribution.

To the best of our knowledge, PA combined with Ag NPs used in antimicrobial finishing has not yet been reported. The antimicrobial activity against *E. coli* and *S. aureus* and durability against repetitive washing of the PA@Ag NPs decorated cotton were well investigated This study has developed a simple, facile and time-saving route to fabricate cotton fabrics with outstanding antimicrobial activity by in situ deposition of Ag NPs into cotton fabric matrix in combination with environmental benign PA, which plays an important dual role as both capture agent for Agþ and stabilizing agent for the formed Ag NPs. The obtained fabrics exhibited excellent and durable antibacterial activities against both S. aureus and E. coli. After 10 laundering cycles, the bacterial reduction rate for CPAF was still above 99%. The results of AAS, SEM, EDS, FTIR, XRD and XPS confirmed that the silver nanoparticles have been fixed and well dispersed on the cotton fibers at the chemical state of Ag0 with size distribution between 58.6 ± 14.7 nm. The PA was of benefit to Ag distribution and bonding on the fabric with a consecutive enhancement in antibacterial properties and durability against wash.

4. CONCLUSION

A single step green process for the preparation of antimicrobial nanotextiles by wet chemical and sonochemical methods. The scanning electron microscopy (SEM) images showed uniform deposition of the nanoparticles on cotton fabrics. The AgNPs-deposited cotton fabrics showed excellent antibacterial activities against gram positive and gram negative bacteria namely, Escherichia coli (E-coli), Staphylococcus aureus, Pseudomonas aeruginosa, and Bacillus subtilis. This work presents a significant advancement in the preparation of

antimicrobial nanotextiles by a smart combination of green synthesis and in situ deposition approach. The successful deposition of Ag NPs on cotton fabric was verified by SEM, EDS and XPS. The bacterial reduction rate against E. coli and S. aureus for the as-treated fabrics was above 99%, even after 10 laundry cycles. The phytic acid was found of benefit to distribution and bonding of silver on the cotton fabric, which might lead to the enhancement of antibacterial property and durability against wash. This study may provide a green, novel and simple strategy to manufacture Ag-based antibacterial cotton for potential applications in textile industry.

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