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Nanotechnology for Antimicrobial Textile Finishing – A Review

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Abstract:

The application of metal nanoparticles to impart special properties to textiles is carried out worldwide for a long time. The current pandemic situation has created great demand and market for apparel and textiles that provide protection from pathogenic microbes. Many research studies are going on in developing durable antimicrobial agents using nanotechnology. The application of nanoparticles as antimicrobial agents has gained momentum in the past decade, as they are durable and last for several laundry treatments like bleaching and washing. This article tries to review the commonly used methods of synthesizing nanoparticles, generally used metal nanoparticles to impart antimicrobial functionality to textiles.

Keywords **— nanotechnology, nanoparticle, anti-microbial, polymerization.**

I. INTRODUCTION

Many innovative finishes are applied to textile materials, to impart novel properties. In recent times, due to the COVID pandemic situation, the awareness of people towards a healthy lifestyle has increased and led to the creation of a great market for health and hygiene products. A lot of research is being encouraged and funded, to develop antimicrobial textiles, to give protection from the spread of infectious diseases. Microbes are omnipresent. They multiply rapidly under suitable conditions such as heat, humidity, and food [28]. Microorganisms could be pathogenic or non-pathogenic. Pathogenic microbes get attached to the textile surface easily, multiply quickly, damage the

I. PAGE LAYOUT

An easy way to comply with the conference paper

Nanotechnology:

Nanotechnology is one of the branches of technology, that deals with altering the properties of materials at the atomic and molecular levels. Nanotechnology can be used to alter the properties of materials, to synthesize and to develop the next generations of improved materials, devices, structures, and systems [7,8]. Nanoparticle size falls in the range of 1 to 100 nm. [7]

nanotechnology is defined as the understanding, manipulation, and control of matter at the above-stated length scale, such that the properties of materials (individual atoms, molecules, and bulk matter) can be engineered, synthesized, or altered to develop the next generations of improved materials, devices, structures, and systems [12]

Nanotechnology in textile applications:

Nanotechnology has made many breakthroughs possible in various fields, which were not considered feasible earlier. A wide range of processes and finishes are applied to textile materials to alter or add functionality. Many additional properties such as antimicrobial, UV-protection, and self-cleaning are imparted to textile materials for value addition. Though these finishes improve functionality, they are not able to withstand the various laundry procedures such as washing, dry cleaning, ironing, etc. Nanotechnology for the application of textile finishes can make the properties durable, due to the high surface area to volume ratio and high surface energy of nanoparticles. These finishes can be imparted without altering the texture, breathability, and absorbability of textiles.

The Nano-Tex was the pioneer in the application of nanotechnology in textile finishing. This is a subsidiary company of US-based Burlington Industries [7,2]. Areas of nanotechnology textile applications include the sports industry, skincare, space technology, and clothing as well as materials technology [34], for better protection in extreme environments [7,8].

Method of application of nanomaterials:

Nanoparticle application imparts specific functionality to textiles Special functions and properties can be imparted to textiles, by adding nanomaterials in the manufacturing and finishing process; these nanomaterials are either added to the spinning dope, thus making them part of the fiber composition or applied as a surface coating, onto the textile. The coatings consist of nano-particles, a surfactant, and a carrier medium. Various methods are used for coating nanomaterials, such as spraying, transfer printing, washing, rinsing, and padding. The most commonly used method of application of the coating is padding. [7, 1]. The nanoparticles are applied to the fabric, with the help of a padding material under suitable pressure and speed followed by drying and curing [7].

Padding is the most commonly used method of coating. The nanoparticles are applied to the fabric, with the help of a padding material under suitable pressure and speed. The fabric will be dried and cured after this procedure.

Nanotechnology – antimicrobial finish:

Many factors influence the selection of materials from which, nanoparticles can be prepared. They are, aqueous solubility and stability, size of the particle, permeability, biodegradability, toxicity, etc. nanoparticles are prepared from polymers by the following methods [41]

i. Dispersion of the polymers
ii. Monomer polymerization
iii. Ionic gelation of the polymer.
iv. Other procedures such as Particle Repulsion in Non-wetting Templets (PRINT) and Superficial Fluid Technology are also used for the preparation of nanoparticles [8, 9].

Inorganic metal and metal oxides are proven to be highly effective in imparting antimicrobial properties and they can withstand difficult conditions of processing [38, 39]. Of the inorganic materials, metal oxides such as TiO_2, ZnO, MgO, and CaO are of particular interest as they are not only stable under harsh processing conditions but also generally regarded as safe materials for human beings and animals [40]. The application of silver and zinc nanoparticles is considered a feasible option to prevent the spread of infections due to their proven antimicrobial properties. The antimicrobial properties of these metal nanoparticles are governed by their size, shape, morphology, and crystallinity [35]

I. **Dispersion method**: dispersion method is classified into [41]

i) Solvent evaporation method
ii) Spontaneous emulsification method
iii) Salting out/ emulsion diffusion method
iv) Non-aqueous phase separation method

i) **Solvent evaporation:** the polymers are dissolved in an organic solvent like chloroform or acetone. The synthetic antimicrobial agent is dissolved in the polymer solution and transferred to an aqueous phase that contains a surfactant to form an oil-in-water emulsion. The evaporation of the organic solvent is done by continuing the homogenization process for a sufficient period of time and the nanoparticles are collected by ultracentrifugation.

ii) **Spontaneous emulsification method:** This is a modification of the solvent evaporation technique. In this method, water-miscible solvents like acetone or methanol are used as the organic phase I, and water-immiscible solvents such as dichloromethane chloroform are used as the organic phase II. Even though this method produces significantly smaller-sized particles, there are some disadvantages such as the presence of a residual organic solvent.

iii) **Emulsion diffusion method:** water-soluble polymers are dissolved in a highly concentrated solution of electrolytes or non-electrolytes to obtain a viscous gel. This viscous gel is added to an organic phase to obtain an oil-in-water emulsion by vigorous stirring. The nanoparticles are formed by adding an excess amount of water, which diffuses the acetone.

iv) **Non-aqueous phase separation method:** This method is suitable for both hydrophilic and lipophilic drugs [90]. The drugs which have an affinity for water are dissolved in water and then added to the organic phase. The non-hydrophilic drugs are dissolved in a polymer solution. Once the aqueous phase and organic phase are mixed to form an emulsion, a second organic non-solvent such as silicon oil is added by vigorous stirring. This process involves the extraction of the first organic solvent, which causes phase separation and the formation of a polymer coacervate. The polymer coacervate combines with the drug molecules to form drug-loaded nanoparticles.

II. Emulsion polymerization method:

Monomers such as poly alkyl cyanoacrylates are mechanically polymerized in the presence of a drug to obtain drug-loaded nanoparticles. In the presence of a stabilizing agent and a surfactant, the monomers are dispersed an aqueous medium, which is having acidic ph. The anions initiate the polymerization process.

Antimicrobial nano-finish:

Nanoparticles made from heavy metals like nano silver, nanoparticles of zinc oxide, and titanium dioxide, are used to impart effective anti-microbial properties.

Commonly used antimicrobial agents may belong to organo-metallics, organo-silicones, QAS (quaternary ammonium salts), and phenols. Among these, the bis-phenolic compounds were found to be having antimicrobial efficacy against a broad spectrum of bacteria.

Nano-silver: [43] Nanotechnology finishing for antimicrobial textiles is primarily done by the application of silver nanoparticles to fibers and fabrics. Silver has been used since ancient times to impart protection against and applied to air filters and water-storing containers. The conversion of free silver to ionic silver leads to the killing of microbes by cell membrane penetration. Textiles are the second leading category of consumer items that use nanosilver to create antimicrobial properties. Although no definite problems have been identified with nano silver use in textiles, some concern has been expressed regarding their eventual residence in the larger environment. Based on their good antimicrobial function and nontoxicity, silver nanoparticles have been used effectively for improving wound healing. It was found that , silver nanoparticles (40 nm) can be used for postsurgical wound healing. Due to the broad spectrum bactericidal and fungicidal activity, silver nanoparticles are used in a diverse range of consumer products. A wide range of nano silver applications has emerged in consumer products ranging from disinfecting medical devices and home appliances to water treatments.

Antimicrobial action of nano-silver: Due to the electrostatic attraction between silver ions and sulfur proteins, silver ions can adhere to the cell wall. The adhered silver ions will make the microbial cell wall highly permeable, ultimately leading to breakage of cell wall. After the free silver ions enter into microbial cells, respiratory enzymes may be deactivated, generating reactive oxygen species. Reactive oxygen species can accelerate the disruption of cell membrane.

Zinc oxide nano-particles: [42] Zinc oxide nano nanoparticles(NPs) are metal oxides with selective toxicity to bacteria with minimal effect on human and animal cells. Zinc oxide is used as one of the ingredients in itch and pain relief products like sunscreens, ointments, and enzymes. Zinc oxide microcrystals absorb UV radiation. Impact of zinc oxide on the impact of these nanoparticles depends on their morphology, particle size, exposure time, concentration, pH, and biocompatibility. The nanoparticles of zinc oxide are proven to show efficient properties such as bactericidal against wide spectrum bacteria and also antimycotic against many types of fungi. When the light falls and activates the zinc oxide nanoparticles, the nanoparticles penetrate the bacterial cell wall via diffusion.

The ZnO NPs may cause cell death by destroying lipids and proteins in bacterial cell membranes, by production of reactive oxygen species (ROS), which are key processes resulting in antibacterial activity. The formation of hydrogen peroxide from ZnO NP surfaces also leads to inhibition of bacterial growth. The SEM and TEM images proved that the zinc oxide nanoparticles disintegrate the microbial cell wall and interact with biomolecules, leading to the death of the microbe.

Titanium dioxide nano particles: [44] Titanium dioxide (TiO2) nanoparticles are proven to be effective against microbes due to their photocatalytic functionality. They are non-toxic, economical and chemically stable and are identified as Generally Recognized as Safe (GRAS) substance. Many studies found that, they have exhibited excellent antibacterial and antifungal properties against a broad range of both Gram-positive and Gram-negative bacteria. When a titanium dioxide coating is exposed to UV light, it reduces water vapor in the air and produces free oxygen radicals that attack microbes like bacteria, viruses, mold spores and other organic compounds on surfaces. The titanium dioxide coatings can be applied to most hard or soft fixed surfaces.

Other antimicrobial Nano-particles:

Iron Oxide and Gold : [45] Fe_3O_4 nanoparticles and gold (Au) represent an additional class of antimicrobial material agents, that are being researched for their use in health care. Fe_3O_4 in its bulk form and Au are inert and lack antimicrobial properties. However, these materials can be modified to impart antimicrobial properties when synthesized as nano-size particles. Microbiological assays have proved that surfaces modified using Fe_3O_4 nanoparticles demonstrate anti-adherent properties and significantly reduce both Gram-negative and Gram-positive bacterial colonization. Au nanoparticles and nanorods have been reported to be bactericidal when photothermally functionalized. In comparison to Ag, gold- (Au-) nanoparticles are less potent and have almost no antibacterial effect by themselves. Nevertheless, Au-NM bound to antibiotics such as ampicillin, vancomycin, the antibacterial enzyme lysozyme, and even other Nano materials were bactericidal to many multidrug-resistant pathogens, including those which were penicillin and vancomycin-resistant.

Copper Oxide: [46] Copper oxide (CuO) nanoparticles have been shown to be effective against various bacterial pathogens, however, their antibacterial efficacy is considered to be inferior to that of Ag or ZnO. Therefore, compared with other metal nanoparticles, higher concentration of copper oxide nanoparticles are required for antimicrobial applications. However, copper is much less expensive than other metal nanoparticles, it can be utilized for improving the antimicrobial efficacy in the form of nanocomposites.

Conclusion: The antibacterial mechanisms of NPs are still unclear. Many studies found that, the antibacterial activity of nanoparticles is due to the oxidative stress, whereas for other NPs, such as MgO NPs, the antibacterial mechanism may not be associated with the regulation of bacterial metabolism. An ideal antimicrobial nanoparticle should stop the growth of bacteria and fungi, should be durable for the life of the fabric by withstanding bleaching and washing, should not have any undesirable effects on fabric, should not interfere with the comfort properties, safe to the wearer, and should be compatible with other finishes and dyes. The nanoparticles should permanently adhere to the

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