Effect of Coating with Silver Nanoparticles (AgNPs) on Cotton Fabric Functional Properties

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Abstract:
In the last decade, the advent of nanotechnology has spurred significant developments and innovations in this field of textile technology. Fabric finishing has taken new routes and demonstrated a great potential for significant improvements by applications of nanotechnology. In this study fabric which is used by workers in Al-Ahram Newspaper (commercial press) has been coated using silver nanoparticles (AgNPs) to improve its functional properties for satisfying the final use requirements. Experimental tests (physical and functional tests) were carried out and comparisons have been made before and after treatment, this was done with reference to durability, efficiency and appearance.

Keywords: Nanotechnology, fabric finishing, silver nanoparticles (AgNPs), Nano textile coating, functional properties.

1. Introduction
The properties and performance of textile fibers are essential to fabric manufacturing and utilization. While it is well known that fabrics made of cotton fibers provide desirable properties, such as high absorbency, breathability, and softness for wear and comfort, expanded utility of cotton fabrics in certain classical and especially non classical applications is somewhat limited due to the fiber's relatively low strength, less than satisfactory durability, easy creasing, easy soiling, and flammability. On the other hand, fabrics made with synthetic fibers generally are strong, crease resistant, antimicrobial, and dirt resistant. However, they certainly lack the comfort properties of cotton fabrics. (1) Nanotechnology induces enticement to develop Nano fibers with the advantages of both cotton and synthetics. A wide range of fiber size or thickness can be utilized in textile processing as shown in fig.(1).

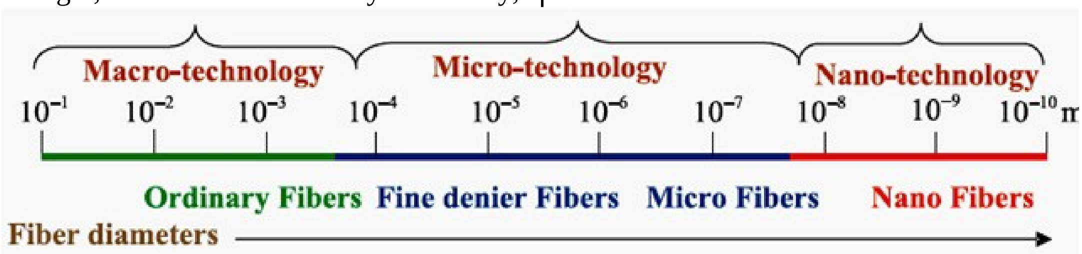


Fig.(1) Fiber size and associated manufacturing technologies. (2)

1.1. Nanotechnology finishing
Finishing of fabrics made of natural and synthetic fibers to achieve desirable hand, surface texture, color, and other special aesthetic and functional properties, has been a primary focus in textile manufacturing. (1) Nanotechnology provides plenty of efficient tools and techniques to produce desirable fabric attributes, mainly by engineering modifications of the fabric surface. (3) For example, the prevention of fluid wetting towards the development of water or stain-resistant fabrics has always been of great concern in textile manufacturing. The basic principles and theoretical background of water or stain-resistant fabric surface interaction are well demonstrated by altering the surface features on a fabric, thus a more control of wetting behavior can be attained. That alteration in the fabric's surface properties is capable of exhibiting the "Lotus-Effect," which demonstrates the natural hydrophobic behavior of a leaf surface. This sort of surface engineering, which is capable of replicating hydrophobic behavior, can be utilized in developing special chemical finishes for producing water or stain- resistant fabrics. (4) In recent years, several attempts have been made to utilize similar concepts of surface-engineered modifications through nanotechnology to develop certain high-performance fabrics. (3) The developments in the areas of surface engineering and fabric finishing have many ways in which

the surface properties of a fabric can be manipulated and enhanced, by implementing appropriate surface finishing, coating and altering techniques, using nanotechnology as shown in fig.(2). [2] There is also a wide range of functional fabrics finishing can be obtained by using a microencapsulation technique. This technology, for example, can be used to develop odor eliminating finishes of fabrics. Fire retardant and anti-microbial agents can also be microencapsulated for advanced fabric finishing. [5]

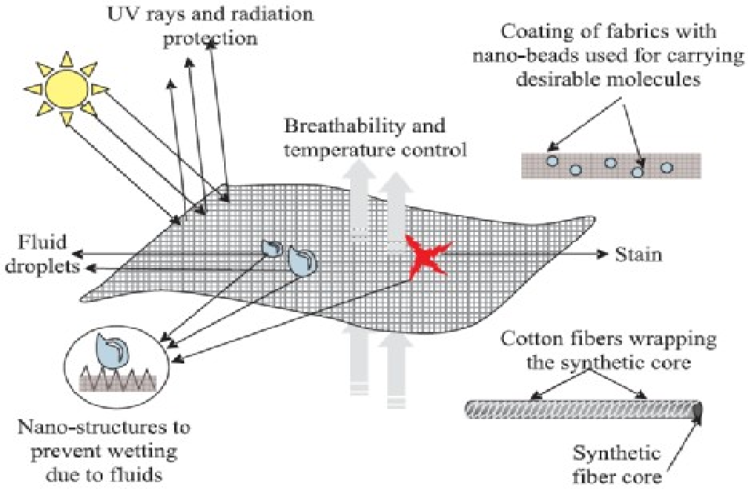


Fig.(2) Fabric finishing for functional properties and performance. (2)

1.2. Nanotechnology fabric properties

Most treatments in this regard have developed several fabric attributes, such as durability, softness, tear strength, abrasion resistance, wrinkle-resistance, breathability, softness, comfort, permanent anti-static behavior, electromagnetic resistance, infrared protection, ultraviolet resistance, flame resistance and aesthetic characteristics. [2]Nano care technology is applied on cellulosic fibers as cotton, to produce wrinkle-resistant and shrink-proof fabrics by using the Nano-engineered cross-linking agents during the fabric finishing process. Such finishing is also capable of eliminating toxic agents, while maintaining the desired comfort properties of cotton. [6] On the other hand, Nano dry technology provides hydrophilic finishing to synthetic fabrics, as this Nano-based finish allows the fabric to remove away the contact body's sweat, which quickly evaporates to provide comfort to the wearer. [7]

1.3. Types of Nano particles for apparel applications

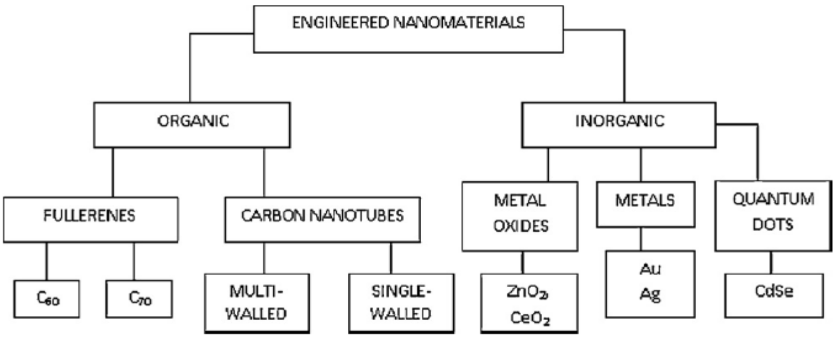


Fig.(3) Nanomaterial classification according to their physical and chemical properties. (10)

By combining the Nano particles with other organic and inorganic substances, the surfaces of the textile fabrics are modified to achieve functional properties as shown in fig.(3). For example, zinc oxide ZnO and titanium dioxide Nano particles TiO2 have been utilized for ultraviolet UV protection. They also provide anti-static effects because they are electrically conductive materials. [8] Static charge usually builds up in synthetic fibers such as nylon and polyester because they absorb little water. Cellulosic fibers have higher moisture content to carry away static charges, so that no static charge will accumulate. Such material helps to effectively dissipate the static charge which is accumulated on the fabric. Similarly, by using Nano sized silicon dioxide SiO2, an additive significant improvement in the strength and flame-resistance of textile fabrics can be achieved. [9] Silver nanoparticles AgNPs are used in apparel applications, including a wide range of functional properties this paper is concerned with this type of nanoparticles.

1.4. Applications of nanotechnology in apparel

Within the last decade, nanotechnology based progress in textile fibers, yarns, and fabric finishing have led to the development of several new and improved textile products. The various applications of nanotechnology for the textile industries are shown in fig.(4). [2] Throughout history, the textiles have been used worldwide in a very wide range of consumer applications. Natural fibers, such as cotton, silk, and wool, along with synthetic fibers, such as polyester and nylon, continue to be the most widely-used fibers for apparel manufacturing. Natural and synthetic fibers generally have different characteristics, which make them ideally suitable mainly for apparel. Depending on the end-use application, some of those characteristics may be good, while the others may not be as good to contribute to the desired performance of the end product. [6] As stated previously, nanotechnology brings the possibility of combining the merits of natural and synthetic fibers, such that advanced fabrics that complement the desirable attributes of each constituent fiber can be produced. Many companies have already made significant progress in the development of improved apparel. Their fabric finishing products are now widely available to the textile apparel industries for clothing, active wear, casual and business clothes, uniforms, etc. [11]

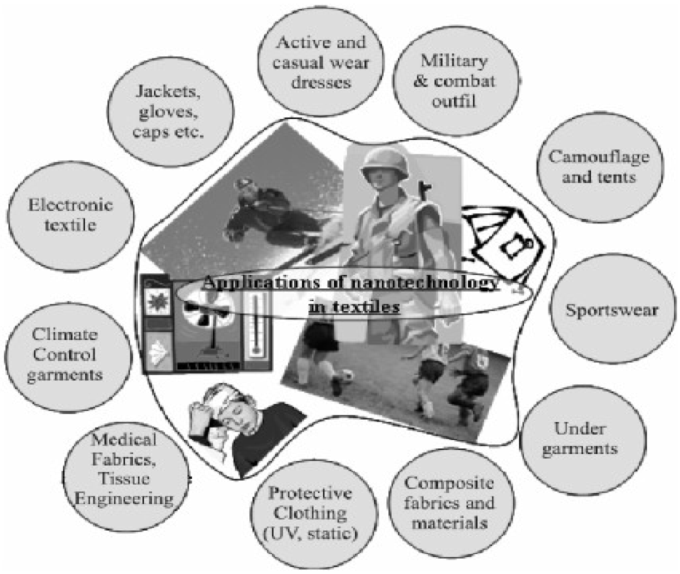


Fig.(4) Some applications of nanotechnology in apparel. [2]

1.5. Silver nanoparticles (AgNPs) for textile coating

Silver nanoparticles (AgNPs) are used in antimicrobial applications, including a wide range of consumer goods and apparel. This innovative fiber protection, based on nanotechnology, is a water and oil resistant impregnator for textiles. The product develops an almost invisible film on the surface around the fibers. As a result, dry dirt cannot adhere to the material and liquid cannot be soaked up by the fibers. Water, coffee and fatty substances are repelled from the treated textiles. Even excessive soiling can be removed easily and without a trace.

1.6. Advantages of silver nanoparticles (AgNPs) coating

- Easy handling
- Harmless to skin
- Environmentally friendly
- Breathability remains
- Suitable for all textiles
- Washing stable up to 40°C
- Dry cleaning resistant
- Ironing resistant
- Simply wash off contaminants
- Long lasting sealing of textiles
- Prevents tea, coffee and ketchup stains etc.
- Long lasting protection for textiles against water, dirt and grease
- The look, texture and breathability of the material remains

1.7. Silver nanoparticles (AgNPs) coating in apparel applications

It is ideal for clothes made of wool, silk, synthetics and leather. It can be applied on every textile from finest silk to hard wearing cotton on different garments such as uniforms, costumes, suits, jackets, shirts, blouses, sports jackets, hiking clothes, ties, trousers, track suits, jeans, rain coats, motorcycle clothing, anoraks, ski clothing, snowboard clothing and even adventure wear. (12)

2. Experimental work

2.1. Fabric specifications

Fabric which is used by workers in Al- Ahram newspaper (commercial press) has been coated using silver nanoparticles (AgNPs) to improve its functional properties to satisfy the final use requirements. Detailed specifications of fabric are mentioned in Table1.

Table1 Specifications of fabric before treatment

Fabric structure	Fiber type	Warp/cm	Weft/cm	Weight (gm/m^2)	Thickness (mm)
Twill3/1	Cotton	22	22	207	0.5

2.2. Experimental tests

A number of tests, determining performance and function were used.

All tests were done in conditioned atmosphere of 20ºC ± 2 and 65% ± 2 RH.

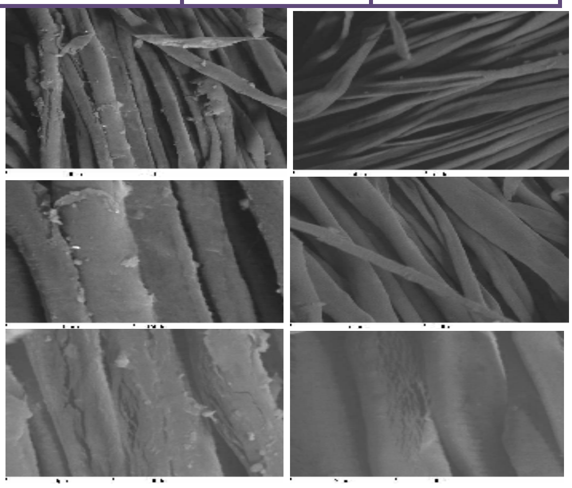
Average of three readings has been obtained for each property. Mass (Weight) obtained using digital sensitive scale according to (ASTM D3776-96-2003). (13) Thickness obtained using thickness tester according to (ASTM D1777-96-2003). (14) Tensile strength and extensibility obtained using tensile tester according to (ASTM 1682-82). (15) Air permeability test was carried out by using electronic air permeability tester according to (ASTM D737-86). (16) Water repellency test was carried out by using Spray tester, according to (AATCC 22-92). (17) Water permeability test was carried out by using Atic Hydrost Head Tester, according to (ASTM D583). (18) Soil release test (oily stain release method), according to (AATCC 130-2010). (19) Bacterial and microbe resistant test was carried out by using Colony Counter Tester, according to (ASTM F2944-12). (20)

3. Results and Discussion

3.1. Effect of silver nanoparticles (AgNPs) treatment on fabric surface

This type of electron microscope produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. (21

It's clear from the previous fig.(5) that treated particles coated the fibers and penetrates them, despite the look and texture of fabric remains. In addition fibers before treatment were destroyed by the electron beam, while after treatment they became resistant to it.



Before treatment After treatment

Fig.(5) Scanning electron measurements for the fabric before and after treatment using a scanning electron microscope (SEM)

3.2. Effect of silver nanoparticles (AgNPs) treatment on fabric physical properties

Table2 Physical properties before and after treatment

Physical properties	Before treatment	After treatment
Weight (gm/m^2)	207	215
Thickness (mm)	0.5	0.51

3.2.1. Effect of silver nanoparticles (AgNPs) treatment on fabric weight

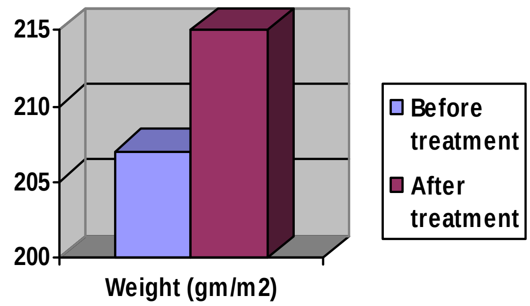


Fig.(6) Weight before and after treatment

Table2 and fig.(6) indicate that fabric weight increases after treatment $8gm/m^2$ than before treatment this can be attributed to the Nano particles which coated the fibers and penetrates them.

3.2.2. Effect of silver nanoparticles (AgNPs) treatment on fabric thickness

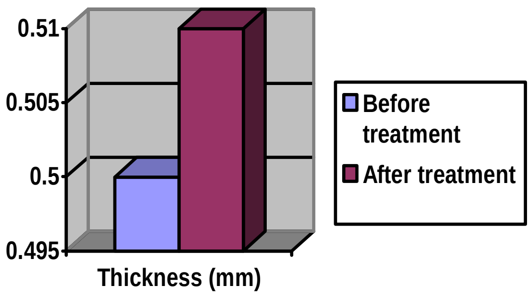


Fig.(7) Thickness before and after treatment

As shown in table2 and fig.(7) thickness after treatment increases a little bit than before treatment this can be referred to the very thin Nano film on the surface and around the fibers. This film is invisible with naked eye as the look and texture of fabric remains.

3.3. Effect of silver nanoparticles (AgNPs) treatment on fabric functional properties

Table3 Functional properties before and after treatment

Functional properties	Before treatment	After treatment
Tensile strength (kg)	40	60
Elongation (%)	35	20
Air permeability (cm^3/cm^2.sec.)	16.64	18.05
Water repellency (rate)	0	100
Water permeability (L/m^2.sec.)	0.675	0.675
Soil release (level)	1	4
Bacterial and microbe numbers (CFU/g)	745	420

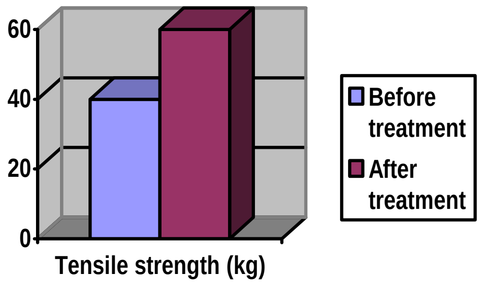


Fig.(8) Tensile strength before and after treatment

3.3.1. Effect of silver nanoparticles (AgNPs) treatment on fabric tensile strength

Table3 and fig.(8) shows that fabric tensile strength increases after treatment than before treatment this can be explained by the Nano particles which coated the fibers and penetrates them, thus make fabric more durable and long lasting.

3.3.2. Effect of silver nanoparticles (AgNPs) treatment on fabric elongation

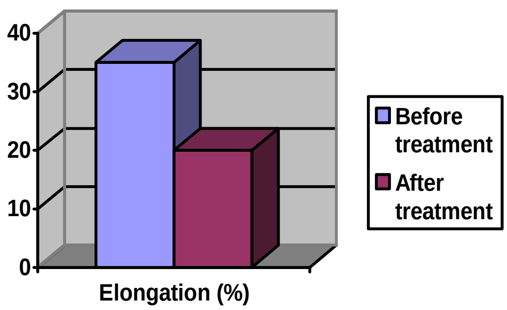


Fig.(9) Elongation before and after treatment

Table3 and fig.(9) clarify that fabric elongation decreases after treatment than before treatment this can be attributed to that spaces between fibers after covering with Nano particles decreases, therefore they extensibility decreases.

3.3.3. Effect of silver nanoparticles (AgNPs) treatment on fabric air permeability

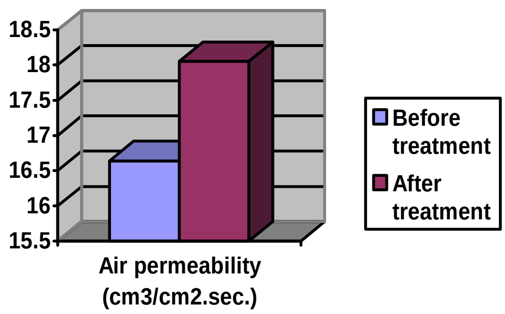


Fig.(10) Air permeability before and after treatment

Despite Nano film coated the surface and fibers of fabric, air permeability increases after treatment than before treatment as shown in table3 and fig.(10) this indicates that the breathability improves by Nano treatment.

3.3.4. Effect of silver nanoparticles (AgNPs) treatment on fabric water repellency

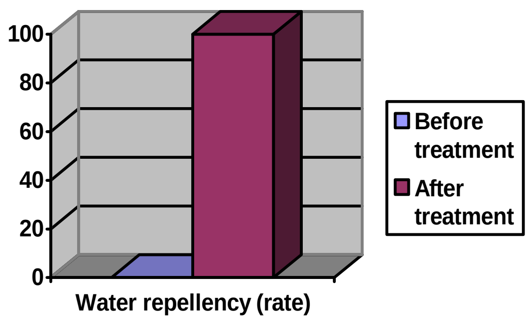


Fig.(11) Water repellency before and after treatment

Note: Water repellency 100 means no sticking or wetting of upper surface. While 0 means complete wetting for whole of upper and lower surfaces. (17)

It's clear from table3 and fig.(11) that The treatment improves the water-repellent property of fabric. There was completely wetting for whole of upper and lower fabric surfaces before treatment while after treatment there is no sticking or wetting of upper surface. This makes cotton fabric exactly waterproof. This can be attributed to the spaces between the fibers are smaller than the typical drop of water, but still larger than water molecules; water thus remains on the surface of the fabric. However, sweat can still pass through the fabric therefore the performance is permanent while maintaining breathability.

3.3.5. Effect of silver nanoparticles (AgNPs) treatment on fabric water permeability

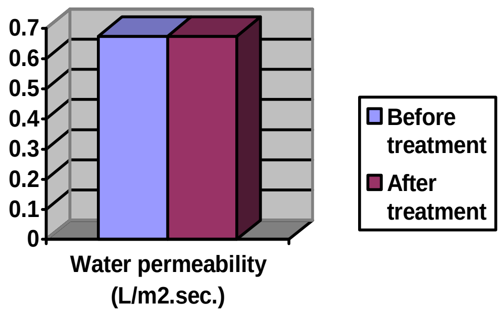


Fig.(12) Water permeability before and after treatment

As shown in table3 and fig.(12) water permeability of fabric is the same before and after treatment. On the other hand the ability to repel water changed completely as we explained previously. This can indicate that sweat permeable through fabric to get rid from it, which offers comfort in wearing.

3.3.6. Effect of silver nanoparticles (AgNPs) treatment on fabric soil release

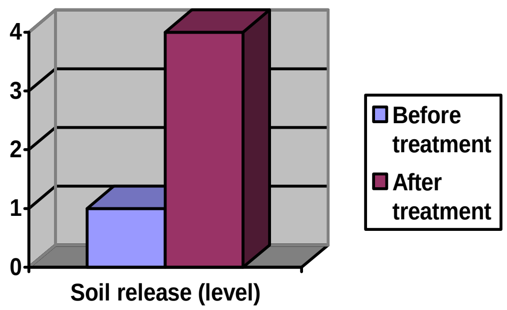


Fig.(13) Soil release before and after treatment

Note: Soil release (oily stain release) evaluated according to AATCC where stain rated on a scale from 5 to 1. As 5 means high soil release while 1means none soil release. (19)

Table3 and fig.(13) shows that fabric before treatment has no soil release while after treatment it prevents soil very good. This mechanism is similar to the lotus effect occurring in nature. Lotus plants have super hydrophobic surfaces which are rough and textured. Once water droplets fall onto them, they slopes slightly and roll off. As a result, the surfaces stay dry even during a heavy shower. Furthermore, the droplets pick up small particles of dirt as they roll, and so the leaves of the lotus plant keep clean even during light rain. Protection for textiles against dirt and grease gives an aesthetic appeal which gives an added value. Especially whereas cleaning oily stains from cotton fabrics is very difficult.

3.3.7. Effect of silver nanoparticles (AgNPs) treatment on fabric bacterial and microbe resistance

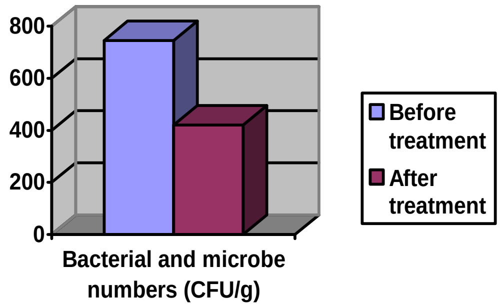


Fig.(14) Bacterial and microbe numbers before and after treatment

Note: Bacterial and microbe resistant measuring unit is (CFU/g) where CFU means Colony Forming Unit. Comparison between bacterial number before and after Nano treatment is an estimate of viable bacterial or fungal numbers. Unlike direct microscopic counts where all cells, dead and living, are counted, CFU estimates viable cells. The appearance of a visible colony requires significant growth of the initial cells plated at the time of counting the colonies it is not possible to determine if the colony arose from one cell or 1,000 cells. Therefore, the results are given as CFU/mL (colony-forming units per milliliter) for liquids and CFU/g (colony-forming units per gram) for solids to reflect this uncertainty (rather than cells/mL or cells/g). (22)

It's clear from table3 and fig.(14) that bacterial and microbe resistance increases after treatment as numbers of bacteria and microbe decreases (there is an inverse relationship between them). This improvement makes fabric ideal for various applications specially cotton fabric is highly affected with bacteria and microbe in presence of moisture or humidity.

Conclusion

Coating cotton fabrics with silver nanoparticles (AgNPs) has a significant effect on performance and functional properties. Silver nanoparticles coating makes a very thin film that is invisible with naked eye as the look and texture of fabric doesn't change after treatment. Silver nanoparticles treatment makes fabric more durable and long lasting. Despite the treatment makes cotton fabric exactly waterproof, it's breathable and sweat can still pass through the fabric therefore it's comfortable. Whereas cleaning oily stains from cotton fabrics is very difficult. Treatment with silver nanoparticles earns fabric self- cleaning property, achieving an aesthetic appeal. It should be known that cotton fabric is highly affected with bacteria and microbe. While after silver nanoparticles treatment, it became anti-bacterial and anti-microbe, that makes fabric suitable for various applications such as medical clothes.

From all the above results authors believe that there was certain accepted advantages by coating cotton fabrics with silver nanoparticles which effecting on function properties of apparel. This useful information can be used by the sportswear and work wear designers. Finally authors recommend Al-Ahram newspaper (commercial press) to apply the treatment on workers coats and overalls.

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