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Eco-friendly Surface Treatment of Cotton Fabric Using Silver Nanoparticles

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THE utilization of high performance textiles and the increasing concern of environmental and ecological issues have grown. The processing requirement for creative finishing technologies e.g. nanotechnology, to give the request useful properties in various textile sector applications, without unfavorably influencing the earth has become in link manner. This research work was focused on using silver nanoparticles (AgNPs) with particle size >100 nm, for treating cotton fabrics and compares such treatment with those previously treated physically with microwave for 2 minutes followed by AgNPs. These finishing techniques were evaluated via the following measurements: fourier transform infrared spectroscopy FTIR–ATR, X-ray diffraction XRD, scanning electron microscope SEM with energy dispersive X-ray analysis EDX, mechanical properties, conductivity, biological and dyeing characteristics. The results clarified the importance of such modification with tiny amount for improving the properties of cotton samples and render multi functionality, besides samples previously treated with microwave for 2 minutes clarified superior improvement in properties compared with their corresponding treated with AgNPs only. The main role of nanoparticles treatment is to increase the surface area per unit volume of treated samples without affecting its chemical structure and the energy of microwave is to activate the surface and alter such treatment.

Keywords: Silver nanoparticles, Cotton fabrics, Antibacterial, UPF, Conductivity, Microwave, FTIR–ATR, XRD, SEM (EDX).

Introduction

Nanomaterials constitute a bridge between atomic, molecular and bulk systems. These materials are of interest because at this scale, material properties can change dramatically giving unique and quite different properties. With only a reduction in size and no change in the chemical structure, materials can exhibit new properties such as electrical conductivity, insulating behavior, elasticity, greater strength, different color and greater reactivity characteristics [1-3]. As dimensions reach the nanometer level, interactions at interfaces of Phases become largely improved and this is important to enhance materials properties. In this context, the surface area to volume ratio of materials employed in the preparation of hybrid nanomaterials is crucial to the understanding of their structure-property relationships. In brief, the two main known reasons why materials at the nano-scale can have different properties are increased relative surface area and new quantum effects. Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength. Also, at the nano-scale, quantum effects can become much more important in determining the properties and characteristics of the materials, leading to novel optical, electrical and magnetic behaviors [4,5]. Nanomaterials can be used in many fields such as: sunscreens, cosmetics, sporting goods, stain-resistant clothing, tires and electronics, special propose coatings as well as many other everyday items, and are used in medicine for purposes of diagnosis, imaging and

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drug delivery [6].

Various types of inorganic particles have been used in polymer/nanoparticles nanocomposites including metals(e.g. Al, Fe, Au, and Ag) metal oxides (e.g. ZnO, Al_2O_3, $CaCO_3$ and TiO_2) non-metal oxides (e.g. SiO_2) and others (e.g. SiC). Selection of the correct nanoparticles depends on the desired thermal, mechanical, and electrical properties of the resulting nanocomposites. For example, aluminum oxide (Al_2O_3) nanoparticles can be used for their high conductivity; calcium carbonate ($CaCO_3$) particles are selected because of their low cost; and silicon carbide (SiC) nanoparticles are used because of their strength, hardness and corrosion resistance [7, 8].

There are two ways to modify the surface of inorganic particles. The first is accomplished through surface absorption or reaction with small molecules. The second method is based on grafting polymeric molecules through covalent bonding to functional groups existing on the surface of the particles. The advantage of the second procedure over the first lies in the fact that the polymer-grafted particles can be designed with the desired properties through a proper selection of the species of the grafting monomers and the choice of grafting conditions [9].

This research work was focused on studying and evaluating the multi functionalization of cotton samples treated with silver nanoparticles and compares these with other samples treated firstly with microwave for two minutes followed by treatment with AgNPs.Thus, the following measurements were carried out:

1- Physical evaluation i.e. fourier transform infrared spectroscopy(FTIR – ATR), X-ray diffraction (XRD), scanning electron microscope (SEM) with energy dispersive X-ray analysis (EDX), tensile strength and elongation percent, air permeability, crease recovery angle.
2- Electrical properties i.e. conductivity measurement.
3- Biological characteristics i.e. ultraviolet protection factor (UPF), antibacterial activity.
4- Dyeing properties i.e. dyeability expressed as color strength (K/S) and fastness grades.

Experimental

Materials and chemicals

Pure cotton fabrics: weight is 177.18gm/m^2, thickness is 0.47mm, the samples were purified in the laboratory according to the reported method [10].

The following chemicals were used in this study silver nanoparticles (AgNPs) size < 100nm product of Aldrich, acrylic binder i.e. tertialy-butyl methacrylate, isopropanol as dispersion, guar gum (xanthan) as thickener, and reactive dye i.e. remazolbrilliant yellow, C.I.37.

Treatment methods

Samples in the form of strips were conditioned at constant temperature ($20^{\circ}C 2 \pm$), and relative humidity (64 ± 4 %). These conditioned samples were treated as follows:

Treatment I: Five samples were treated with AgNPs with five different concentrations (1, 2, 4, 10, and 15)$^x 10^{10}$ ppm.

Treatment II: Samples were firstly exposed to microwave for 2 minutes followed by treatment with AgNPs with the above-mentioned concentrations.

The treatment was carried out as follows: AgNPs, propanol, acrylic binder and xanthan gum with a ratio 1:1:1/2:1/4 were added to 250ml deionized water, stripes of conditioned samples were immersed in the prepared solution using the pad-dry curing method. The treated samples were washed with 2gm /L sodium lauryl sulphate, then rinsed in distilled water and left to dry at ambient conditions[11,12].

Testing and Analysis

Physical techniques

Fourier Transform Infrared Spectroscopy with Attenuation Total Reflection (FTIR – ATR)

The FTIR spectra of cotton samples were recorded by means of Nicolet 380, in the wave length range 650-4000 cm^{-1}. The FTIR spectra absorbance frequencies of the samples were recorded with an average 64 scans and resolution of 4 cm^{-1}.

X-ray Diffraction (XRD)

The XRD of samples were carried out by Scintage Inc. diffractometer (USA). The recorded diffraction angle (2θ) ranging (0-60°) with a scan rate 2°/minute.

Scanning Electron Microscope (SEM)

The SEM model Quanta 250 FEG (field Emission Gun) attached with EDX unit (energy dispersive X-ray analysis) to clarify the surface morphology of samples.

Mechanical measurements

1- Tensile strength and elongation percent of the samples were carried out using Tinius Olsen, SDL, UK, according to standard method ASTMD 3822-2007.

2- The air permeability of the examined fabrics was evaluated using Air Permeability Tester, SDL, UK, according to ASTM D737-04(2008).

3- The crease recovery angle of the samples was evaluated using AATCC test method 66-2008.

Electrical properties measurements

The conductivity of the samples was determined using E 4980A Precision LCR meter 20Hz to 2MHz 49. The measurements were determined by averaging 6 measured values for each sample.

Biological evaluation

The ultraviolet protection factor UPF of the samples was evaluated; it is defined as the reduction of the amount of UV radiation that passes through the fabric to the skin. Measurements were carried out with test method AATCC183-2004. The transmissions of the samples were measured using visible spectrometer Perkin Elmer (lambada 35) with integrating sphere.

Antibacterial evaluation

This test was carried out according to standard method AATCC 107-2004. Two types of bacteria were used, Staphylococcuis (S.aureus) as gram-positive (G+ve), and Escherichia coli (E.coil) as Gram-negative (G-ve).

Dyeing characteristics

The treated cotton samples were dyed with the reactive dye (reactive yellow C.I. 37) using the exhaustion dyeing method. The color strength of the examined samples was measured with Color Eye 3100 spectrophotometer 3100 SDL, England.

Fastness to light, rubbing and washing was carried out and evaluated each according to its standard methods: AATCC xenon lamp exposure 169-2003, ISO 105/DO2-1993, ISO 105/C06-2010, respectively.

Results and Discussion

Normally, there is no attraction between inorganic particles and polymeric materials such as textile. The surface energy between these two types causes a kind of repellency in the interface. This problem is intensified by using nanoparticles because they have high specific surface area [13]. Consequently, surface modification with nanoparticles is not permanent. The irradiation of textile materials using surface treatment such as microwave, in this research work, is to generate some active radical groups on the surface of fabrics to combine with particles. The energy of microwave photons is quite low compared with the chemical bond energies. Thus, microwave does not directly affect the molecular structure of the compound and do not change the electronic configuration of atoms[14].

In this research work, the samples were firstly treated with microwave for 2 minutes as a source of surface modification and eco-friendly tool, saving energy and time without any damage in sample properties.

Characterization of the treated samples

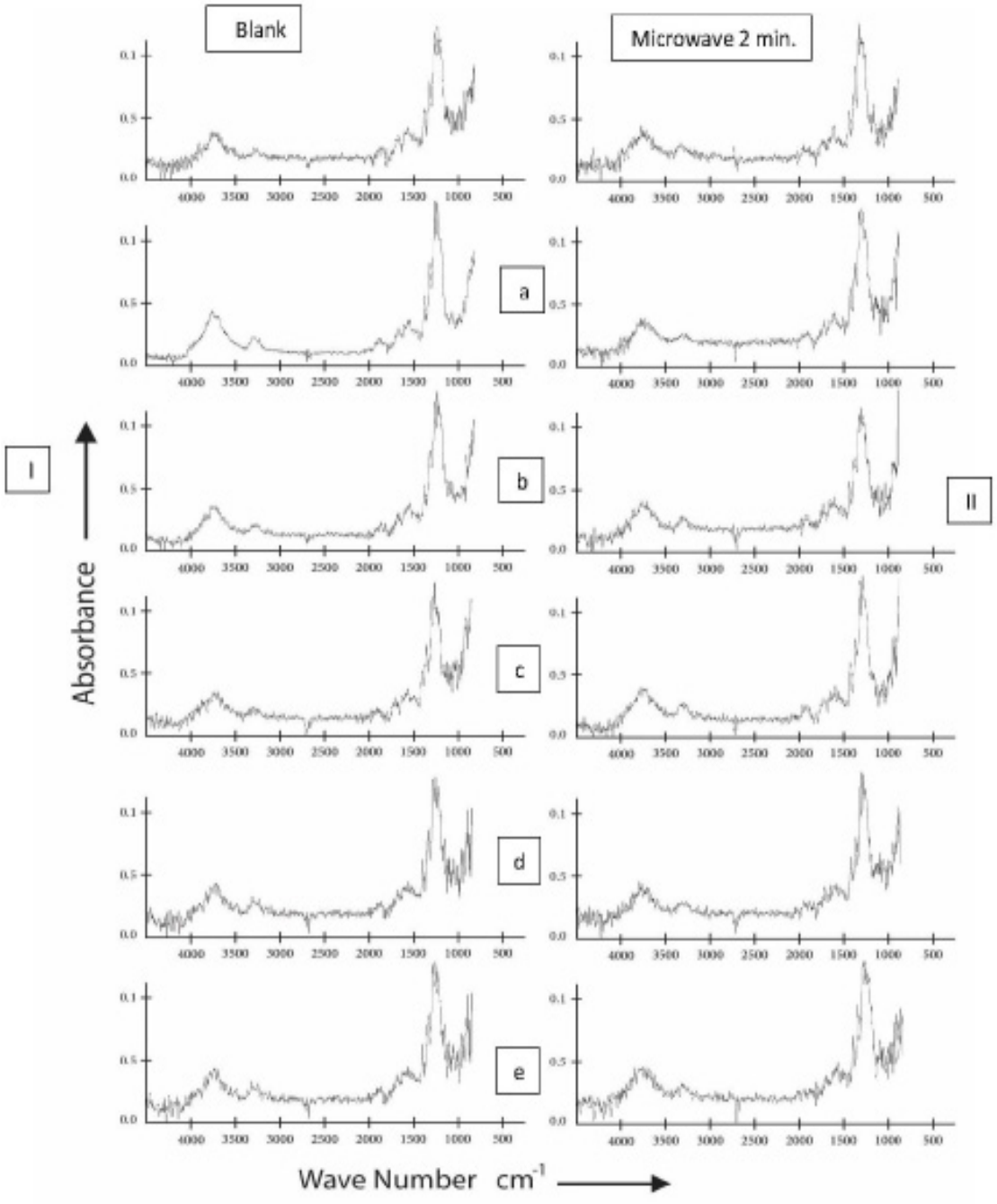
Fourier transform infrared spectroscopy (FTIR-ART)

Figure 1(I) and (II) shows (FTIR-ATR) spectroscopy of cotton samples with different treatments: microwave for 2 minutes, microwave and /or different concentrations of silver nanoparticles (1, 2, 4, 10, and 15) X 10^3 ppm. whereas (I) refers to samples treated with the above mentioned concentrations of AgNPs and (II) refers to that irradiated for 2 minutes microwave followed by treatment with different concentrations of AgNPs.

It is clear from the FTIR spectra that:the characteristic absorption peaks corresponding only to polymeric substrate and there is no shift for these characteristic peaks with different treatments i.e. the above treatments do not affect on the chemical structure of cotton sample which means that the interaction between fabrics and metallic silver nanoparticles only results from physical absorption of silver on surface of treated samples [15]. Besides, the role of microwave is to activate the surface of polymeric substrate to attack more AgNPs, while the role of both acrylic binder and xanthan gum aid in more attraction, and fixation of the absorbed AgNPs [16].

Table 1 shows the change in peak intensity values of the major absorption bands of different functional groups exist in cotton samples. The intensity of these functional groups clarifies a noticeable increase on treatment with microwave indicating enhancement in the amounts of polar groups on the surface leading to increase the hydrophilic character of the treated samples.

Microwave energy heats the fabric uniformly, such heating improves the physical properties of samples and the chemical reactions can be accelerated due to selective absorption of microwave energy by polar molecules [17]. On treating both the blank cotton samples and that treated with microwave with different concentrations of AgNPs, a gradual increase in intensity of all the functional groups is observed, and treatment II showed higher increase compared to treatment I, these results can be attributed to the presence of common functional groups in acrylic binder, xanthan gum and cotton samples[18]. Also, such polymers are well known for their ability to coordinate with metal Ag and



I: refer to samples treated with different [AgNPs].
II: refer to samples treated with microwave for 2 minutes followed by different [AgNPs]

Fig. 1. FTIR-ATR spectra diagram of cotton fabrics: I (a-e): samples treated with different [AgNPs] (1,2,4,10,15) ×10³ppm, II (a-e): samples treated with microwave 2 minutes followed by the same [AgNPs].

TABLE 1. Comparison the change in peak intensity values of the functional groups of cotton samples.

Treatment	Functional groups											
	O-H (~3300cm^{-1}) Stretching vibration		C-H (~2900cm^{-1}) Asymmetric Stretching		C=O Asymmetric stretching (~1600cm^{-1})		C-C (~1430cm^{-1}) Stretching in ring		C-H In plan bending (~1340cm^{-1})		C-H bending aromatic ring (~667.2cm^{-1})	
blank	61.5		24.6		18.5		18.2		23.5		29.7	
MW (2min.)	62.7		25.7		19.1		19.0		24.1		31.2	
[AgNPs] $\times10^3$ppm	I	II	I	II	I	II	I	II	I	II	I	II
1	63.6	64.4	26.9	29.0	19.9	23.5	19.2	21.9	26.6	27.9	30.5	31.9
2	67.3	68.0	30.6	33.1	21.5	25.2	19.6	20.2	27.2	31.4	31.7	32.4
4	66.9	75.1	32.6	32.9	23.0	28.2	20.3	21.8	28.2	34.1	32.9	35.5
10	74.5	77.6	32.2	35.2	24.8	27.4	20.8	22.6	27.9	33.9	31.4	34
15	76.4	79.2	34.4	36.9	28.3	31.5	21.7	23.7	29.5	36.7	33.9	39

I: refer to samples treated with different [AgNPs].
II: refer to samples treated with microwave for 2 minutes followed by different [AgNPs]

are considered as excellent host for AgNPs via electrostatic interaction.

X-ray diffraction

Figure 2 shows X-ray diffraction spectra of cotton samples under test. It is clear that different bands are appeared and centered at 2 θ≈ (15^o, 17^o, 22^o, 34^o) all these peaks having broad band except that at 2θ ≈ 22 shows sharp bands. The broadness of the peak relates to amorphous phase, while sharpness means crystalline phase [19,20]. Also, two sharp bands are appeared at higher concentration of AgNPs for both types of treatment I, II at 2θ ≈ (38^o, 44^o).

Table 2 shows the change in peak intensity values that interpreted by the change in crystallinity/ amorphousity ratio, [21] it is clear that most of bands having lower intensity values than that its value in blank in spite of the gradual increase in intensity of all the bands for both types of treatment, samples treated with microwave only showed high peak intensity values than that of blank the peak intensity values of sample II is higher than that of sample I. The increment in crystallinity/ amorphousity ratio means an increase in crystalline regions and vice versa for the decrease in ratio. The crystalline index which measures the crystalline region in the fiber is determined, [22] the results of Table 2 shows an increase in crystalline index with microwave treatment and both types of treatment, this means more crystalline regions means highly ordered metallic coating of AgNPs, i.e. increasing surface area/unit volume and rendering the textile more conductive.

Scanning ElectronMicroscope (SEM) and Energy Dispersive X-ray analysis (EDX)

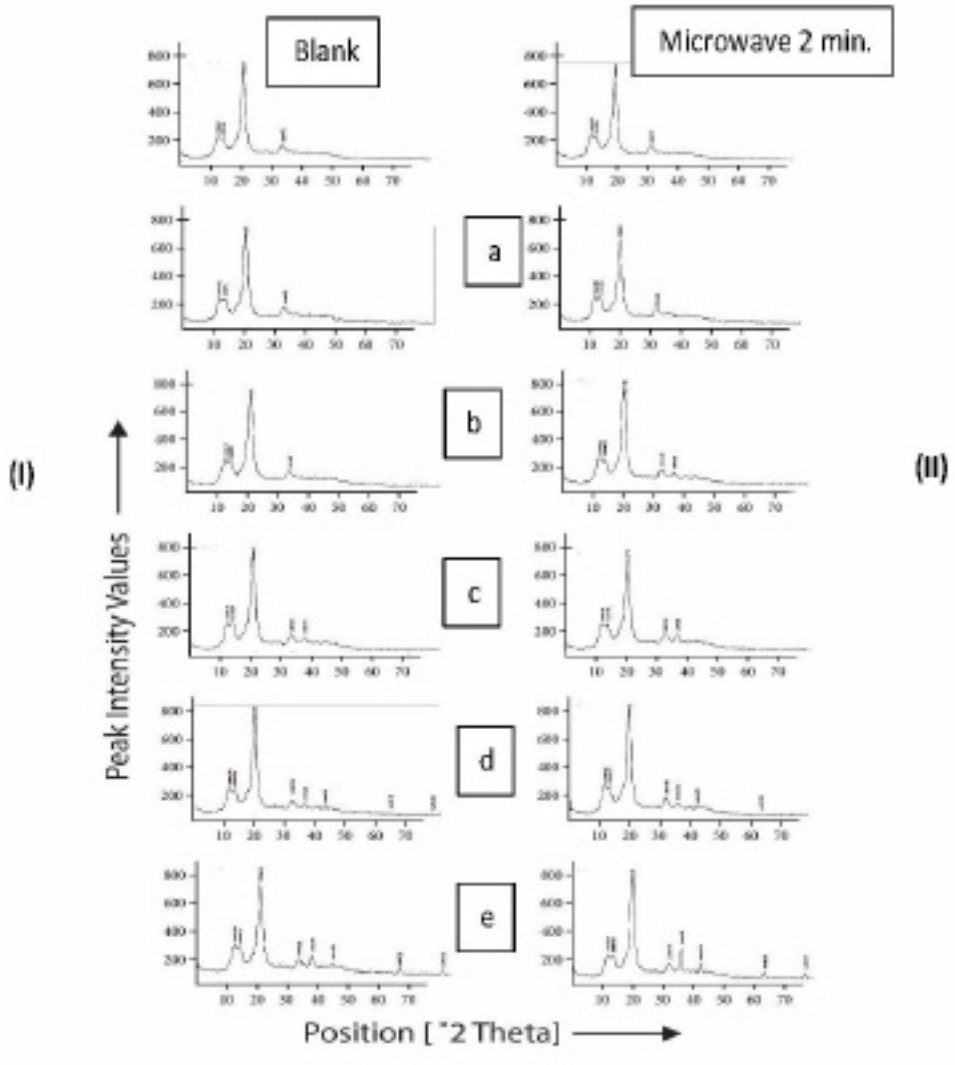
It gives an idea about the morphological changes of the samples caused by deposition of AgNPs on the surface; these images are represented in Fig. 3. It is clear that: (a) blank samples showed typical long fibril structure arranged in order with clear and smooth surface, (b) for samples treated with microwave for 2 minutes, its fibril structure wasdeswelled to some extent, (c) samples treated with AgNPs showed deposition of Ag and higher deposition with higher aggregation are detected with increasing [AgNPs] and microwave treatment.

EDX spectra of the treated samples confirming the existence of silver element on the surface. The peak observed at ≈ 33.5 ke v correspond to binding energies of Ag, no peaks of the other impurities have been detected [23,24]. Also, with increasing concentrations of AgNPs, the intensity of the appeared peak increase, and that treated with microwave showed high intensity than the corresponding treated with Ag only. The results obtained from EDX spectrum together with those of the SEM images are strong evidence of the

deposition of AgNPs on the surface. Besides, Ag is a good magnetic conductor cannot be present in dispersed state and easily to aggregate [25,26].

Mechanical properties

Table 3 shows the change in mechanical properties of cotton samples that include tensile strength and elongation percent, crease recovery angle and air permeability for different cotton samples under test. For sample treated with 2 minutes microwave, there is a slight increase in both tensile strength and elongation percent; such heating uniformity prevents loss in strength offering considerable increase. For treatments I & II, a gradual increase in both tensile strength and percent elongation and treatment (II) showed higher increase than treatment (I). As, mentioned previously in X-ray, there was an increase in crystallinity and crystalline region, this in turn leading to increase in the strength of the polymeric substrate. The percentage increase in both tensile strength and elongation percentage at the highest[AgNPs] was for treatment I: 27.67 % and 73.31, while for treatment II was 39.96 % and 86.5 % respectively. These results agreed well with that obtained in X-ray diffraction, which showed an increase in crystallinity/amorphousity ratio. However more crystalline regions mean



I: refer to samples treated with different [AgNPs].

II: refer to samples treated with microwave for 2 minutes followed by different [AgNPs]

Fig. 2. XRD of cotton fabrics I (a-e): samples treated with different [AgNPs] (1,2,4,10,15) ×10³ppm,II (a-e): samples treated with microwave 2 minutes followed by the same [AgNPs].

TABLE 2. (a) & (b) Comparison the change in crystalline parameters of treated cotton samples.

(a)- Peak intensity values &crystallinity index.

	Peak intensity values at°2θ												Crystallinity Index.	
	15°		17°		22°		34°		38°		44°			
Blank	**200**		**205**		**700**		**120**		**–**		**–**		**66.19**	
MW2 min	**230**		**210**		**710**		**140**		**–**		**–**		**70**	
[AgNPs] ×10³ ppm	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
1	120	135	130	145	370	440	65	85	–	–	–	–	64.86	67.04
2	140	150	152	150	445	460	80	95	–	–	–	–	66.30	67.41
4	150	145	145	170	510	550	100	125	–	–	–	–	67.63	69.09
10	170	210	170	175	500	570	110	105	120	150	65	75	66.29	69.29
5	180	260	185	215	615	740	140	175	130	160	65	85	69.91	70.94

(b) -d-spacing, crystal size &half band width.

Treatment	**d-spacing at°2θ**								**crystal Size(nm)**		**Half band width**	
	15 °		**17°**		**22°**		**34°**					
Blank	**5.79**		**5.34**		**3.88**		**2.58**		**–**		**0.40**	
MW 2min.	**5.88**		**5.34**		**3.89**		**2.59**		**–**		**0.45**	
[AgNPs] ×10³ ppm	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
1	5. 70	5.82	5.19	5.30	3.84	3.88	2.57	2.58	19.3	21.1	0.45	0.40
2	5.82	5.85	5.27	5.33	3.88	3.89	2.59	2.60	20.1	19.3	0.43	0.45
4	5.86	5.89	5.31	5.32	3.85	3.87	2.58	2.59	19.3	18.8	0.45	0.46
10	5.80	5.99	5.34	5.38	3.88	3.89	2.59	2.60	20.1	17.3	0.43	0.50
15	5.87	5.90	5.28	5.41	3.88	3.91	2.60	2.61	21.8	18.8	0.40	0.46

I: refer to samples treated with different [AgNPs].

II: refer to samples treated with microwave for 2 minutes followed by different [AgNPs]

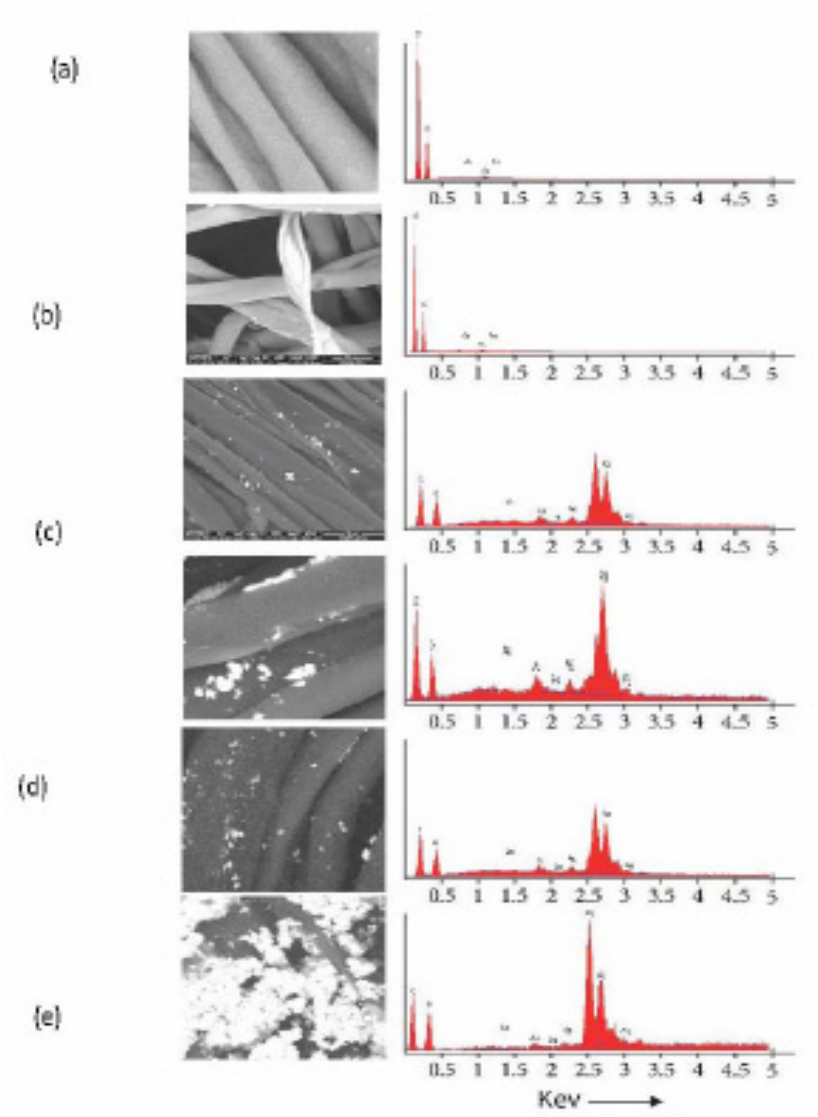


Fig. 3. SEM and EDX of cotton samples (a) untreated, (b) treated with MW, (c) treated with [Ag NPs] 2×10^3, (d) treated with
MW + [Ag NPs]2×10^3, (e) treated with [Ag NPs]10×10^3ppm, (f) treated with MW+ [AgNPs]10×10^3ppm.

highly ordered metallic coating besides increasing of surface area unit volume for treatment with nanoparticles thus conferring strength and rigidity of treated samples [27].

The role of water soluble polymer such as gum and binder are well known for their ability to coordinate with AgNPs and can easily from Ag nanocomposites layer. The polymeric substrate can be considered as an excellent host to stabilize Ag nano composite via electrostatic interaction between the polymeric functional groups and AgNPs and this increase with increasing the concentration of these additives.

The crease recovery angle increases with different treatment, microwave only and/or different concentration of AgNPs. The blank cotton shows crease recovery angles 70° and 100° for warp and weft respectively, it is inelastic due to its crystalline polymer system that makes it difficult to displace so easily to crease and wrinkle ready[28]. The increase increase recovery angle with microwave due to the increase in polarity with treatment via increasing the intensity of the functional group C-H, C-O as previously mentioned in FTIR spectra. Also, with increasing [AgNPs] for both types of treatment and the role of gum and binder render more AgNPs accumulate

TABLE 3. The change in tensile strength (kgf), elongation %, crease recovery angle, and air permeability ($cm^3/cm^2/s$) of the examined samples

Treatment	Test									
	Tensile Strength (kg/f)		Elongation Percent (%)		Crease recovery angle				Air Permeability ($cm^3/cm^2/s$)	
					warp		weft			
Blank	29.95		7.27		70		100		0	
MW 2min.	30.45		9.86		73		150		1.16	
[AgNPs] $\times 10^3$ppm	I	II	I	II	I	II	I	II	I	II
1	32.71	33.28	9.53	10.21	72	84	113	118	0.99	0.93
2	35.03	36.9	10.49	10.87	85	92	115	135	0.91	0.88
4	33.7	37.5	9.83	11.3	98	113	116	132	0.87	0.8
10	36.9	40.2	11.96	12.12	107	128	114	140	0.83	0.77
15	38.22	41.92	12.60	13.56	110	125	123	158	0.78	0.7

I: samples treated with different [AgNPs].
II: samples treated with microwave for 2 minutes followed by different [AgNPs]

and aggregate i.e.increasing the surface area /unit volume.

In considering the air permeability of the treated cotton samples, the results show the permeability index gradually decreases with increasing concentration of AgNPs, and treatment II having lower permeability than treatment I. As it is known, the air flow takes place through the inter-yarn pores; the spacing of yarns is an important parameter influencing the openness of fabric structure. The larger the aggregation and accumulation of nano-silver on the surface of the treated samples, the less the air can penetrate inside the fabric pores, the less the permeability index [28].

Electrical properties

Electrical resistivity is an intrinsic property that quantifies how strongly a given material opposes the flow of electric current; it measures the ability of material to conduct an electric current. Cellulosic fibers have higher moisture content that can carry away static charge, so that no static charge will accumulate. Table 4 shows the change in conductivity with different treatment. As it is known, silver has the highest electrical conductivity among metals (6.2×10^5 s/cm) and on treatment with different concentration of nano-silver, the conductivity increased gradually. The percentage increase at the highest concentration was, 33.02% for treatment I and 94.64% for treatment II.

Biological characteristics

Ultraviolet protection factor (UPF)

The UV radiation consists of transmitted waves that can pass unchanged through the pores of the fabric and scattered waves that can interact with the fabric [29]. It depends on the fiber content and weave, fabric color, finishing processes, presence of additives and laundering. Inorganic UV blocking are more preferable to UV blocker as they are non-toxic and chemically stable under exposure to both high temperature and UV. It was determined that nano-sized titanium dioxide, zinc oxide and AgNPs are more efficient for absorbing and scattering UV radiation than the conventional size, and there are better to provide protection against UV rays. Table 5 shows the category of protection of garments depending on their UV transmission [30].

Table 6 shows the results of UPF under the effect of different treatments. the blank cotton sample take a grade G, for microwave reaches very good, the values gradually increase with

TABLE 4. The change in conductivity of the examined samples treated with, microwave, microwave and/or different [AgNPs].

Conductivity of samples s/m.		Sample
144.23		blank
II	I	[AgNPs]×10³ppm
163.32	152.34	1
187.30	162.54	4
280.74	191.86	10

I: samples treated with different [AgNPs].
II: samples treated with microwave for 2 minutes followed by different [AgNPs]

both types of treatments and reaches to grade excellent, also treatment II having higher values than treatments I. These results are in full agreement with the result of X-ray diffraction whereas the increase in crystallinity/ amorphousity ratio makes the fabric more compact and lower UV transmission thus increasing UPF. Also, it reflects the amount of coated AgNPs on the surface, whereas increasing protection means increasing the amount of coated layer i.e. increasing the surface area/units volume.

As it is known, natural fabrics are easy target for bacteria attack because they retain water. Metallic ions and metallic compounds have some degree of sterilizing effect whereas a part of the oxygen in air or water turned into active oxygen via dissolving organic substance to create sterilizing effects [31]. To study the effect of these treatments on the antibacterial activity, we use two different types of bacterial strains i.e. Staphylococcus aureus (gram positive) and Escherichia coli (gram negative). Table 7 shows that the coated samples performed splendid antibacterial activity, with increasing AgNPs concentration the better the imparted antibacterial activity and treatment II shows higher effect than treatment I [32].

The general consequence for the effect of AgNPs on the bacterial activity is that when elemental silver nanoparticles are in contact with water or dissolved oxygen, silver ion are released from the surface of nanoparticles in accordance with the following equation: [33,34]

$$O_2\,(aq) + 4H + 4Ag \rightarrow 4Ag^{+}(aq) + 2\,H_2o$$

Silver ions might destroy and/or pass through the cell membrane and bound to the – SH groups of cellulose enzymes [35]. This causes a critical decrease in enzymatic activity which might change microorganism metabolism and inhibit their growth, lead to the death of the cell. The silver ions might also catalyze the production of oxygen radicals, resulting in oxidation of the molecular structure of the living organism. The antibacterial activity of all the treated samples towards Escherichia coli was more than towards Staphylococcus aureus, this can be attributed to the difference in sensitivity between them towards AgNPs i.e. thickness and constituents of membrane structure.

Dyeing characteristics of treated cotton samples

Cotton samples under test dyed with reactive dye (Reactive yellow CI (37). Table 8 shows the dyeing characteristics of different cotton samples, the results clarify the following: the color strength (K/S) increasing with microwave treatment, there was a gradual increase in (K/S) with increasing [AgNPs] for both types of treatment, samples with treatment II having higher (K/S) as compared with treatment I, the light fastness (L.F.) grading ranging from 3/4:4 on the standard blue scale. The color difference (ΔE) which is inversely related to L.F. grads, gradually decreases with increasing [AgNPs] and treatment II showed lower ΔE values than treatment I. Also, both rubbing and washing fastness showed slight increase on standard gray scale and ranging from 3/4:4. These results can be discussed on the previously mentioned results on FTIR and X-ray diffraction, besides the effect of AgNPs in increasing surface area/unit volume.

TABLE 5. The ranking of the garments depending on the garment UV transmission.

Category of protection	Actual UV Transmission	UPF
Good	4.1-6.7	24-14
Very good	2.6-4.0	39-25
Excellent	≤2.5	≥40

TABLE 6. The change in UPF for the examined samples treated with microwave, microwave and/or different[AgNPs]

Blank	UPF			
	14.15 G.		15.53 G.	
MW2min.	31.92 V.G.		32.28 V.G.	
[AgNPs] $\times 10^3$ppm	I	II	I	II
1	19.86 G.	227. V.G.	17.27 G.	31.12 V.G.
2	32.47 V.G.	33.7 V.G.	23.11 G.	39.2 V.G.
4	37.43 V.G	38.7 V.G.	21.24 G.	45.58 EX.
10	33.65 V.G.	40.28 EX.	31.02 V.G.	41.2 EX.
15	40.56 EX.	45.8 EX.	37.02 V.G.	48.70 EX.

I: samples treated with different [AgNPs].

II: samples treated with microwave for 2 minutes followed by different [AgNPs].

G: Good. V.G.: Very Good. Ex: Excellent

TABLE 7. Antibacterial activity of the treated samples determined by inhabitation zone method (diameter in mm)

Treatment	microorganism			
	Escherichia coli (gram negative) G-		Staphylococcus aureus (gram positive) G+	
Blank	0		0	
[AgNPs] 10^3ppm×	I	II	I	II
1	3،8	6،9	2،4	6،2
2	8،1	14.7	4،9	11،1
4	11،5	15.9	10،2	14،1
10	12،6	15.8	9،3	14،2
15	15،2	18.5	13	16،8

I: samples treated with different [AgNPs].

II: samples treated with microwave for 2 minutes followed by different [AgNPs]

TABLE 8. The dyeing properties of treated cotton sample dyed with reactive dye (Reactive yellow C.I. 37).

Treatment	Dyeing properties													
	K/S		L.F		EΔ		Rubbing		Washing Fastness					
									Alte.		Staining			
											Cotton		Wool	
Blank	**1،95**		**3/4**		**1،573**		**3/4**		**3/4**		**4**		**4**	
MW 2min.	**2 .02**		**3/4**		**1،517**		**3/4**		**3/4**		**4**		**4**	
[AgNPs]10^3 × ppm	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
1	2،74	3،18	3	3/4	1،547	1،427	3	3	3/4	4	3	3/4	4	4
4	3،91	4،05	3/4	3/4	1،455	1،317	3/4	3/4	4	4	3/4	3/4	3/4	3/4
10	4،25	4،20	4	4	1،237	1،290	3/4	3/4	4	4	3/4	3/4	4	4

I: sample s treated with different [AgNPs].
II: samples treated with microwave for 2 minutes followed by different [AgNPs]

Conclusion

- Generally smart textiles can be defined in a view of the fact that they have the abilities to directly react with environmental stimuli such as mechanical, thermal, chemical, electrical and magnetic. As it is known cotton has porous and fibrous nature as well as high permeability, large surface area and hydrophilic functional groups.
- In this research work cotton treated with AgNPsfor enhancing its application in different fields, example given electronic devices and medical field. To enhance the absorption and fixation of AgNPs, the surface was firstly treated with microwave as a source of surface modification and eco-friendly treatment, save in energy and water consumption.
- The comparison was made between samples treated with different [AgNPs] and those treated with microwave followed by different [AgNPs] under the same conditions. The results depicted that the accumulation of AgNPs on the surface of cotton samples increase surface area/unit volume. So, higher [AgNPs] on the surface leads to higher improvement of the properties of the treated samples.
- The treated samples evaluated via spectrometric techniques i.e. FTIR, XRD-EDX. The results of these Characterizations were greatly compatible with the improvement in different properties i.e. mechanical, electrical, antibacterial, UPF and dyeing characteristic.
- Also samples firstly treated with microwave followed by AgNPs showed higher improvement than their corresponding treated with AgNPs.

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المعالجة السطحية الصديقة للبيئة لاقمشة القطن باستعمال جزيئات الفضة النانونية

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يتجه الوعي نحو استعمال منسوجات ذات كفاءة عالية مع الحفاظ على الاحتياطات البيئية. لهذا فان الحاجة لتخليق تجهيزات تكنولوجية جديدة على سبيل المثال استعمال نانوتكنولوجي لتحقيق افضل الخواص في مجال القطاعات النسجية دون الاضرار بالبيئة اصبح الاسلوب المستهدف. لهذا اجري هذا البحث لتحقيق هذه الاهداف عن طريق استعمال جزيئات الفضة النانونية بحجم جزيئي اصغر من ١٠٠ نانوميتر لمعالجة اقمشة القطن و مقارنة هذه المعالجة بنظيرتها السابق تجهيزها عن طريق تعرضها لاشعة الميكروويف لمدة دقيقتين قبل معالجتها بالنانوفضة بغرض الحصول على افضل النتائج. تم تقييم الاقمشة المعالجة بالطرق الآتية: قياس طيف الاشعة الحمراء (FTIR)، اشعة اكس (XRD)، الميكروسكوب الماسح الالكتروني (SEM–EDX) – الخواص الميكانيكية– قابلية التوصيل الكهربائي– الخواص البيولوجية و خصائص الصباغة. اوضحت النتائج اهمية هذه المعالجات باكتساب العينات خصائص متعددة بالاضافة الى اهمية المعالجة السطحية مثل الميكروويف قبل استعمال النانو فضة و اكتسابها خصائص افضل من نظيرتها المعالجة باستعمال جزيئات النانو فضة فقط. و قد تبين ان الدور الاساسي لتلك المعالجات هو زيادة مساحة سطح العينة بالنسبة لوحدة الحجوم دون التأثير على الخصائص الكيميائية و التركيبية للاقمشة. اضافة الى دور الميكرويف في تنشيط سطح العينة و بالتالي اكتساب خصائص افضل.