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Application of DC plasma discharge and /or Nanosilver treatments to Poly (ethylene terephthalate) fabrics to induce Hydrophilicity and antibacterial activity

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ABSTRACT

This research studies the surface modification of poly (ethylene terephthalate) (PET) fabric that was induced by DC plasma discharge for nanosiliver treatments. At first, DC plasma discharge was employed systematically as a function of plasma device parameters under different operating conditions including different time, different current and different hydrostatic pressure employing chemically inert argon or nitrogen as a working gas. The optimization of the best of these parameters were performed by the measurements and evaluation of mechanical properties, air permeability and water absorbency, Electron Spin Resonance (ESR) and the surface morphological changes of pretreated polyester fabrics were observed by Scanning Electron Microscope (SEM) photographic analysis , Then the pretreated PET fabric with plasma by the best conditions are subjected to nanosilver treatment by two different silver concentrations .The antibacterial activity of plasma treated and /or nanosilver treated PET against gram positive bacteria (Staphylococcus aurous) and gram negative bacteria(Escherichia coli) were examined. The results obtained showed that both the hydrophilicity and antibacterial behaviours against gram positive bacteria (Staphylococcus aurous) and gram negative bacteria(Escherichia coli) were highly improved by the treatment of fabric by either individual or combined DC cold plasma or nanosilver treatments.

Introduction

Polyester is hydrophobic, because of the lack of polarity and the extremely crystalline structure of the polymers that resist the entry of water molecule into the polymer system and very good tenacity. It can be surface modified using a variety of techniques including plasma, corona discharge, ion beam, laser treatment, photo-initiated graft polymerization; PET is a suitable substrate for several reasons[(1)]. It contains carbonyl groups that are capable of hydrogen bonding. The pre-treatment and finishing of textile by non-thermal plasma technologies becomes more and more popular as a surface modification technique where this treatment does not require the use of water and chemicals, resulting in a more economical and ecological process [(2)].The objective of plasma diagnostics is to obtain information about the state of the plasma by means of different experimental techniques [(3)]. Knowledge of plasma characteristics is required to understand fully the effects of the different physical processes taking place in the plasma and to deduce from them its properties. The application of plasma treatments for improving wetability of all possible fibre types was obtained with varied success degrees [(4)]. It offers numerous advantages over the conventional chemical processes. A non-thermal (or cold or low temperature) plasma is a partially ionized gas with electron temperatures much higher than ion temperatures. The high-energy electrons and low-energy molecular species can initiate reactions in the plasma volume without excessive heat causing substrate degradation. Non-thermal plasmas are particularly suited to apply in textile processing because most textile materials are heat sensitive polymers [(5)].

Nano-material is often defined as a material that is less than 100 nano-meters in at least one dimension, as one nanometer is a millionth of a millimeter, or a billionth of a meter. Nanomaterials may be either entirely new chemical structures or already known chemical structures at a smaller scale. As a result of their small size, nanomaterials may have entirely different properties and functions. Nanotechnology is concerned with forming and using these small structures. The most reported application of nanoparticles to textile surfaces are [(6)];1) nano-silver (Ag) application that widely used for imparting anti-bacterial properties, 2) nano titanum dioxide TiO_2 nanoparticles for functionalizing uv- blocking property as well as self cleaning property to the applied surface, and finally 3) zinc oxide ZnO nano-particles for anti-bacterial and uv-blocking properties of the applied textile surface. Most of the presented methods [(7)] for stabilizing of inorganic nanostructured materials on the textile surfaces need several steps of preparation, functionalization, final treatment, drying, curing and so on. This is forced high cost and it is very time consuming for high-scale manufacturing production [(8)].

This research aims to evaluate the effect of three different treatments , plasma pretreatments (using Ar or N_2 gas as a carrier), nanosilver with two different concentrations , and finally combined plasma pretreatments (best conditions) with nanosilver. The work was also extended to evaluate the effect of

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these applied treatments on the performance of polyester fabrics in terms of air permeability, water absorbency, mechanical properties, electron spin resonance spectroscopy (ESR), fiber surface morphological changes, and antibacterial activity.

Experimental Work

Materials and Chemicals

- A woven polyester fabric of 108 g/m^2 is provided by 'Ouf Son's' Company, Cairo. Polyester samples 7.5 cm in diameter were cut from a large piece and fully washed and dried at 80^o C.
- Nano-sized silver powder metal based on size <100mm, with assay of 99.5% produced by Aldrich company.

Plasma Pretreatment of the Examined Fabrics

Polyester samples are exposed to DC pseudo plasma discharge using device in Plasma Laboratory, Physics department, faculty of science, Ain Shams University. Schematic diagram of the used device is shown in figure (1). Where the discharge takes place between the cathode and mesh-anode by applying high electrical potential difference 'V'. The DC pseudo plasma discharge treatments were studied at different conditions of pressure, current, and time. The working nitrogen/argon gas pressures used for treatment of samples are: 0.6, 0.4, 0.3 and 0.2 torr. The discharge current applied for each samples is ranged from 15 to 90mA. The exposure time for each sample is ranged from 15 second to 2 minutes.

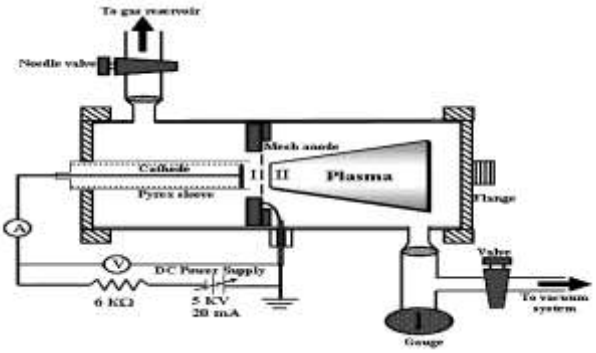


Figure (1): The schematic diagram of DC pseudo plasma discharge device.

Application of Nano-sized Silver:

Plasma exposed and unexposed polyester (blank) samples were treated by two nano-silver concentration of 25 ppm and 50 ppm (expressed in weight/volume. Silver nano-particles were applied on to fabric by exhaustion method on a shaking water bath (Model: SW 22, Manufactured by Julabo, Germany). Application parameters including pH value, temperature, and time were studied. Nano-silver colloidal solutions were shacked before every treatment for homogeneity. Once the required optimum pH and temperature of the nano-silver hydrosol in the bath were achieved, the polyester sample was entered and stirred for 30 minutes at 150 rpm. For all other experiments, generally the treatment was carried out at 40^{o}C for 30 minutes. The treated fabrics were then dried at room temperature without rinsing.

Characterization of the Applied Treatments:

Characterization of Plasma Treated Polyester Samples

Plasma treated polyester samples that were operating at different conditions of pressure, current, and time, then the pretreated samples were characterized by the following measurements:

Air Permeability:

The treated and untreated samples are tested for their air permeability using SDL Air permeability tester, England. The measurements were carried out according to the reported standard method [9]at standard atmospheric conditions (temperature = 20 ±2 ◦C and relative humidity = 65±5).

Water Absorbency Test

The hydrophilicity of plasma treated samples was studied by measuring the time required for water droplet to spread on the fabric surfaces according to the reported standard test method [10].

Mechanical Measurements

The treated and untreated samples are tested for their tensile strength and elongation behaviors using a Shimadzu Universal Tester of (C.R.T) type S-500, Japan, in Polymer Metrology Lab. National institute for standards, Giza, Egypt. Where all measurements were carried out according to standard method for tensile properties of single textile fibers, at standard atmospheric conditions (temperature = 20 ±2 ◦C and relative humidity = 65±5). The measurements were carried out at least three times, and the results listed in this paper are the mean values [11].

Electron Spin Resonance Spectroscopy (ESR)

The ESR spectra of blank (untreated polyester) and plasma treated fabric samples under the effect of different treatment conditions of time, pressure and current was recorded using an X-band ESR spectrometer (Bruker, EMX) at room temperature using high sensitivity standard cylindrical cavity (ER4119HS) operating at 9.7 GHz with a 100 kHz modulation frequency[12].

Characterization of Plasma Treated Polyester Samples by Optimum Conditions

Selected polyester samples exposed to the optimum conditions from each factor including, time, pressure and current are subjected to the following testes;

Scanning Electron Microscope (SEM)

Surface morphological changes of blank untreated and those plasma treated fabric samples using argon/ nitrogen were determined using Scanning Electron Microscope (SEM) of model: manufactured by Jeol 1200 EX II Electron Microscope, Japan, in Central Testing Ain-Shams University Laboratory.

Surface Elemental Analysis

Carbon, hydrogen and nitrogen elements were analyzed in the central laboratory; Ain-Shams University, using Elemental Analyzer, Model 2400 for selected polyester samples exposed to the optimum conditions of time, pressure and current.

Antibacterial properties

Antibacterial behaviours of some selected samples (blank, plasma exposed and nanosilver treated samples) were evaluated according to the reported standard method[13]. The Antibacterial properties of the fabrics were investigated by incubating bacteria solutions of both Staphylococcus aureus (Gram-positive) and Escherichia coli (Gram-negative) at 37°C for 18-24 hours.

Results and Discussion

Optimization of plasma treatment on conditions on PET using Argon or Nitrogen gas

The textile samples were exposed to pseudo plasma discharged of power ranging from 1-20 W. The textile sample of 7.5 cm diameter was placed in front of the mesh anode at an axial distance Z= 8 cm from the mesh. The samples were studied under different conditions of time, pressure and current. The effect of different exposure conditions on air permeability, water absorption, mechanical properties, and electron spin resonance spectroscopy (ESR) were discussed.

Time Effect

The Effect of Plasma Exposure Time on Air Permeability

The results of air permeability values of different plasma treated polyester samples are represented in table (1). It is clear

that, there was a gradually increase in the air permeability values of different plasma/Ar exposed samples in the time range from 15 s. up to 30 s. for plasma/Ar exposed samples. with increasing 20% relative to their blank mates while this increase extended to 45 s for plasma/N_2 exposed samples due to the increase in the porosity of the plasma treated polyester samples, then the air permeability values slightly decreased by increasing the time of exposure up to 120 s and this may be due to the possibility of saturation to occur at extended time which may results in two competing processes—binding of nitrogen molecules to the surface and breaking up of polymer chains to result in the production of low molecular weight fragments[14].

The Effect of Plasma Exposure Time on Water Absorbency

Table (1) also shows the water absorbency values of different plasma treated polyester samples at exposure time ranging from 15 s. up to 120 s.). Where a gradual decrease was observed for the studied range up to 45 s, this may be due to the slight melting of the uppermost fabric surface, which results in plugging the inter-fiber spaces [15]. Extended time for treatment resulted in raising the water absorption in applying both Ar and N_2 plasma treatments.

The Effect of Plasma Exposure Time on Tensile Strength

The treated and untreated samples were tested for their mechanical behavior to study the effect of plasma treatment exposure time on the tensile strength as shown in figure 2. The data manifested by the tensile strength value of plasma/Ar clarify their decreasing up to exposure time 30 s, this is due to increase the amorphosity of treated fabric samples by plasma exposure [16]. Then by prolonging the plasma exposure time the tensile strength remains approximately unchanged up to 60 s. While in case of plasma/N_2 these values decrease gradually along the studied exposure time .The decrease in the tensile strength values by plasma exposure may be due to the thermal effect of this treatment on the fabric structure of the exposed polyester fabrics [16].

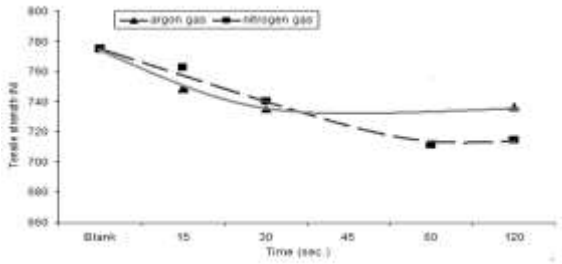


Figure (2): Effect of exposure time on tensile strength of plasma treated samples in a medium of argon gas or nitrogen

The Effect of Plasma Exposure Time on Electron Spin Resonance spectroscopy (ESR)

Figures(3) a,b (1-6) show the changes in Electron Spin Resonance spectroscopy (ESR) intensity values of plasma treated polyester samples in a medium of argon or nitrogen gas at different exposure times respectively. Following up of the variations in these figures we can conclude that plasma treatment of polyester samples resulted in more surface activation of them till 30 s. for plasma/Ar treatments while the increase in surface activation of plasma treated polyester extended to 45 s. using plasma/N_2 treatments. Also a second activation band can be observed on following up of the different appeared peaks by increasing the exposure time [15].

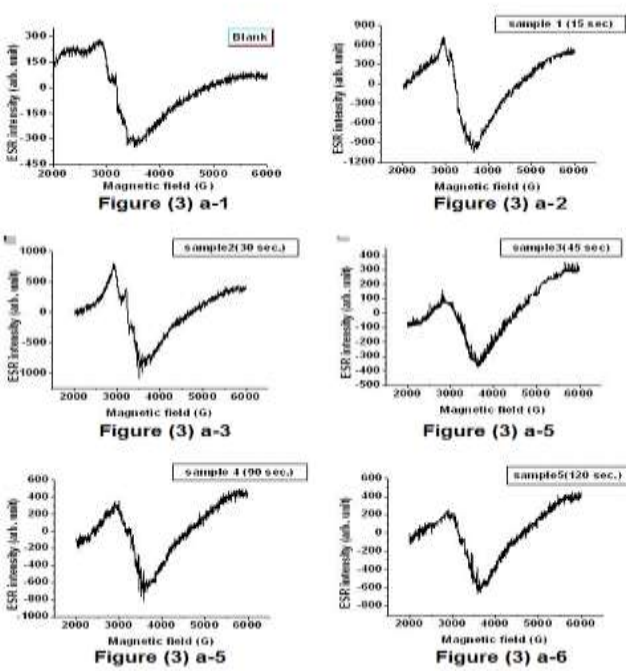


Figure 3a (1-6): The change in ESR Intensity of plasma treated polyester samples in a medium of argon gas at different exposure time

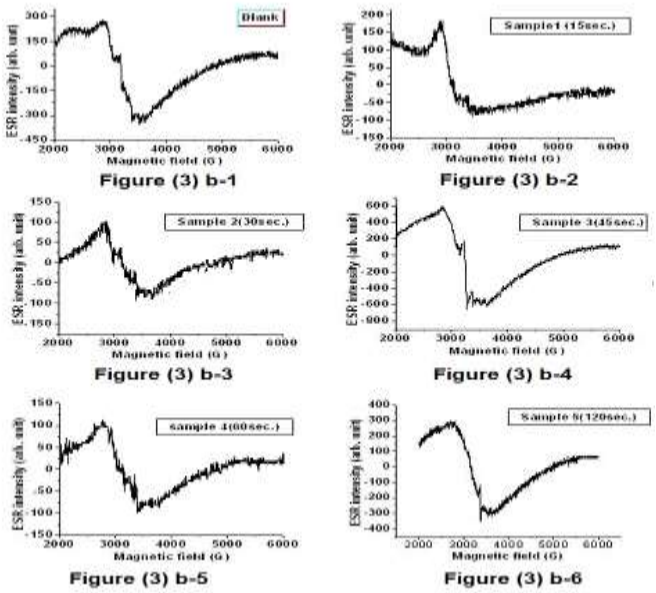


Figure (3)b(1-6): The change in ESR Intensity of plasma treated polyester samples in a medium of nitrogen gas at different exposure times

Current Effect

The Effect of Plasma Current on Air Permeability

Table (2) shows the results of air permeability values of different plasma treated polyester samples using different current. It is clear that, there was a gradually increase in the air permeability values of both plasma/Ar and plasma/N_2 exposed samples in the current range from 40 mA up to 75 mA with increasing by a percent 28.85% for plasma/Ar, while for plasma/N_2 it is 18.14%, relative to their blank mates, due to the increase in the porosity of the plasma treated polyester samples [14]. These results verified the effect of plasma exposure on decreasing the strength of the irradiated samples and hence their

ability to pass air through its structure that is, increasing their air permeability values.

The Effect of Plasma Current on Water Absorption

Table (2) also shows the water absorbency values of different plasma treated polyester samples with the plasma applying current up to 90 mA, where a gradual decrease in these values was observed along the studied range extended to 75 mA, by a percent increase 7.89% for plasma /Ar , and 36.36% for plasma /N_2 relative to their blank mates, this may be due to the melting of the uppermost fabric surface which results in plugging the inter-fiber spaces[14]. Further increased current for treatment resulted in rising in water absorption again in case of both Ar and N_2 plasma treatment.

The Effect of Plasma current on tensile strength

The mechanical behavior of the examined samples was tested to study the effect of plasma treatment on the tensile strength as shown in figure (4). The data manifested by the tensile strength value of plasma argon clarify their decrease up to current of 60 mA in both plasma Ar and N_2 treatment due to the plasma effect which increases the amorphosity of treated fabrics thus weakening their strength [16]. Then by increasing the plasma applied current the fabric melted by the thermal effect of plasma to the extent that provide increasing of the compactness and crystallinity of the fabrics again resulting in increasing of the tensile strength values .

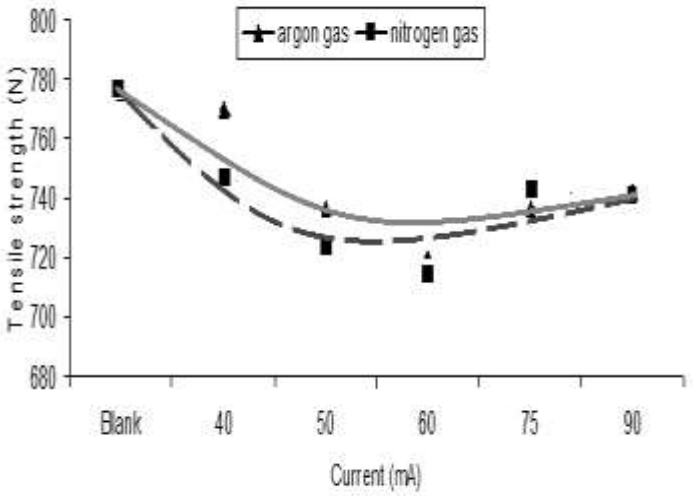


Figure (4): The change in tensile strength values of plasma treated samples in a medium of argon gas or nitrogen gas at different plasma exposed current

The Effect of Plasma current on Electron Spin Resonance spectroscopy (ESR)

Figures(5) a,b(1-6) show the changes in Electron Spin Resonance spectroscopy (ESR) intensity values of plasma treated polyester samples in a medium of argon or nitrogen gas at different current respectively. Following up of these figures we can conclude that plasma treatment of polyester samples resulted in more surface activation which is influenced by increasing amplitude of current extending to 75 mA in case of both plasma/Ar and plasma /N_2 treatments.

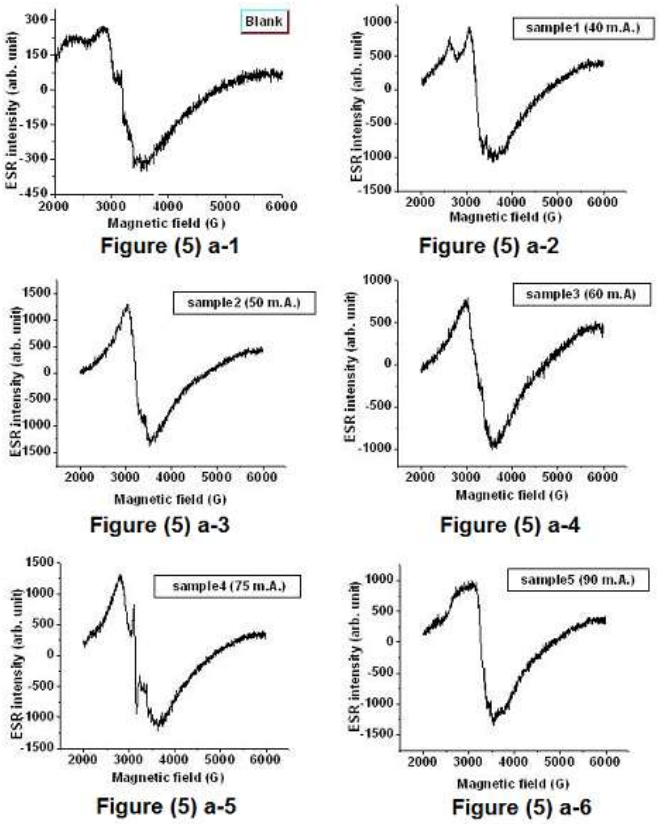


Figure (5)a(1-6): The change in ESR Intensity of plasma treated polyester samples in a medium of argon gas at different plasma exposed current.

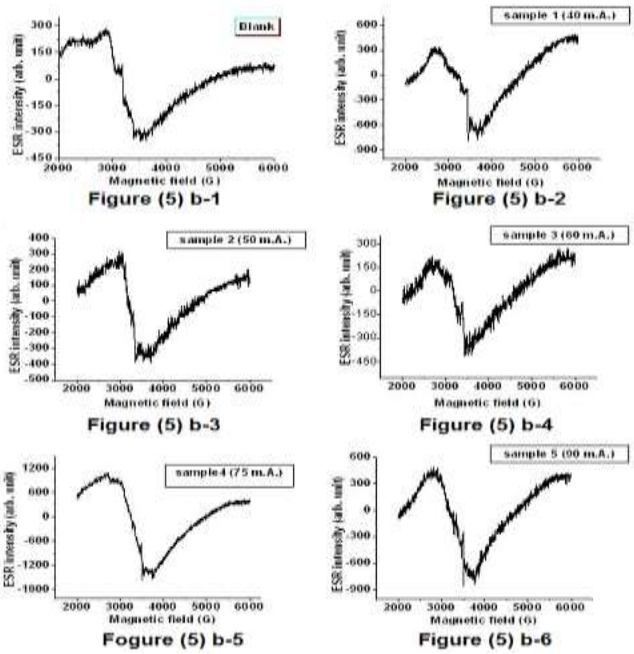


Figure (5)b(1-6): The change in ESR Intensity of plasma treated polyester samples in a medium of nitrogen gas at different plasma exposed current

Hydrostatic Pressure Effect

The Effect of Plasma Hydrostatic Pressure on Air Permeability

Air permeability values of the examined polyester samples increased gradually by increasing the applied pressure in plasma chamber reaching maximum increase using (0.4 torr& 0.6 torr)

in case of Ar and N_2 respectively compared to the values of blank unexposed samples as shown in table (3), this can be explained in view of the effect of pressure on energy of the charged particles leading to a large effect on the fabric surface, thus increasing their permeability in air.

The Effect of Plasma Hydrostatic Pressure on Water Absorption

Considering the effect of plasma carrier gas (N_2 or Ar) pressure in the irradiation chamber on water absorbency as indicated in table (3), it is clear that as the pressure increased water absorbency also significantly increased. This phenomenon can be attributed to the increase in energy of the charged particles leading to a large effect on the fabric surface. At low pressure the gas ions from the plasma are accelerated and implanted into all surfaces of the sample without the preference with regard to the sample orientation or complexity. By this high-energy (low-pressure) gas ion melts the polyester fibers, which in turn results in a decrease in the fabric absorbency [(17)].

The Effect of Plasma Hydrostatic Pressure on Tensile Strength

The results of tensile strength values of the examined samples were shown in figure (6). Where these values decreased up to pressure of 0.3 torr in plasma/ N_2 and 0.4 torr in plasma/ Ar treatment this resulted from the effect of plasma in increasing the amorphosity of treated fabrics thus weakening their strength [(15)]. Then by increasing the plasma hydrostatic pressure the fabric melted by the thermal effect of plasma to the extent that provide increasing of the compactness and crystallinity of the fabrics again resulting in increasing of the tensile strength values[(14)] . Further increase in pressure has no drastic deterioration in the polyester fibers.

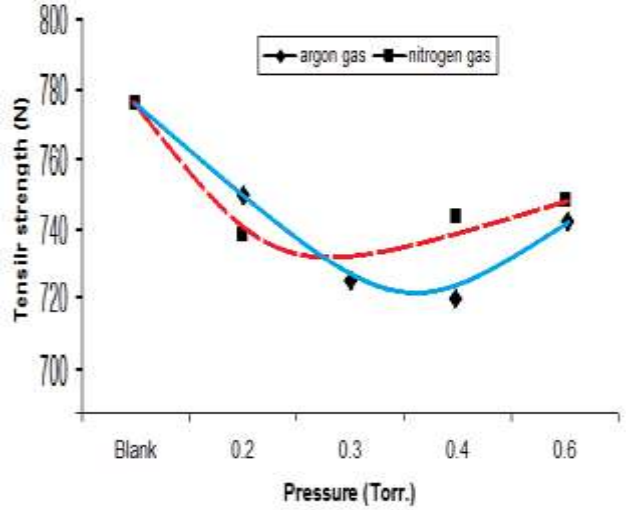
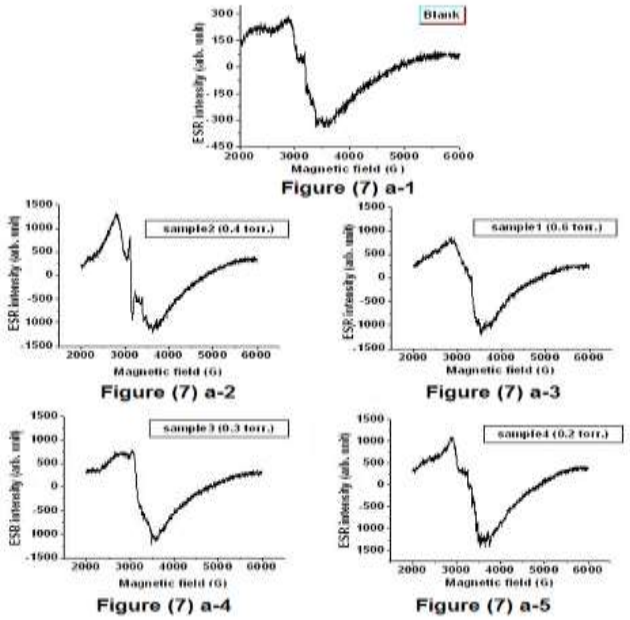


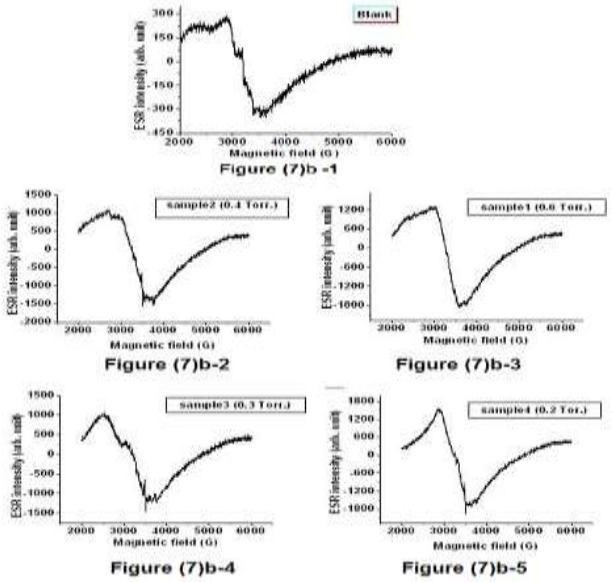
Figure (6): The change in tensile strength values of plasma treated samples in a medium of argon or nitrogen gases at different hydrostatic pressures.

The Effect of Plasma Pressure on Electron Spin Resonance Spectroscopy (ESR)

Figures (7) a,b (1-6) show the changes in Electron Spin Resonance spectroscopy (ESR) intensity values of plasma treated polyester samples in a medium of argon or nitrogen gas at different pressure respectively. Following up of these figures we can conclude that plasma treatment of polyester samples resulted in more surface activation which is influenced by increasing amplitude of pressure extending to 0.3 torr in plasma/N_2 treatments but extending to 0.4 torr in plasma /Ar .



Figures(7)a $_{(1\text{-}6)}$: The change in ESR Intensity of plasma treated samples in a medium of argon gas at different hydrostatic pressures.



Figures (7)b $_{(1\text{-}6)}$: The change in ESR Intensity of plasma treated samples in a medium of nitrogen gas at different hydrostatic pressures.

Characterization of plasma treated polyester samples at optimum conditions

Scanning Electron Microscope (SEM)

On studying the effect of plasma treatment on the fiber morphology by scanning electron microscope photographs as shown in figures 8(a–d). These graphs showed that: 1- the plasma exposure of polyester fabrics have no drastic deterioration in the polyester fibers with their swelling[(16)] and appearance of some nodes on their surface (image -c) compared to blank untreated one (image -a).2- treatment of polyester fabrics with nanosilver (image -b) may resulted also in swelling of the fiber surface polyester[(17)] with the appearance of some nodes on their surface. This effect may be enhanced in using plasma exposure followed by nanosilver treatment of polyester with high performance (image -d).

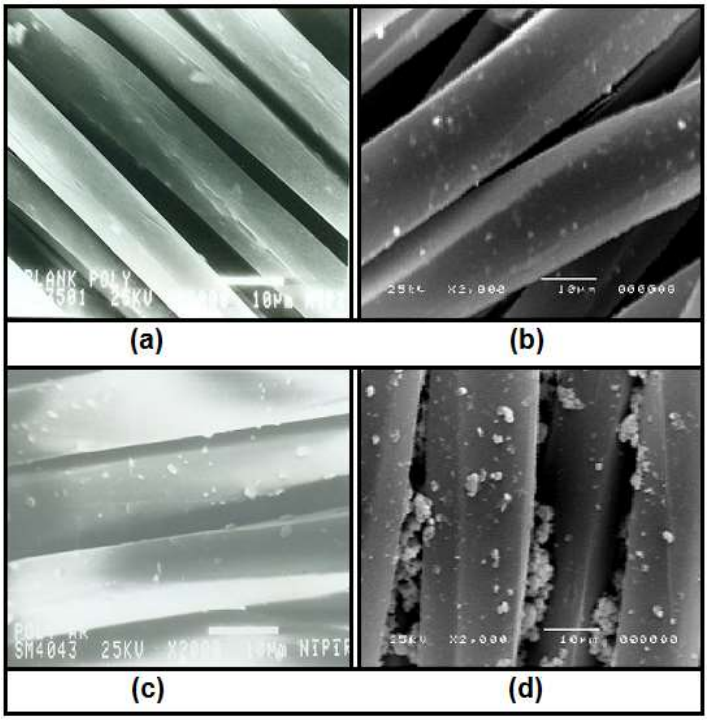
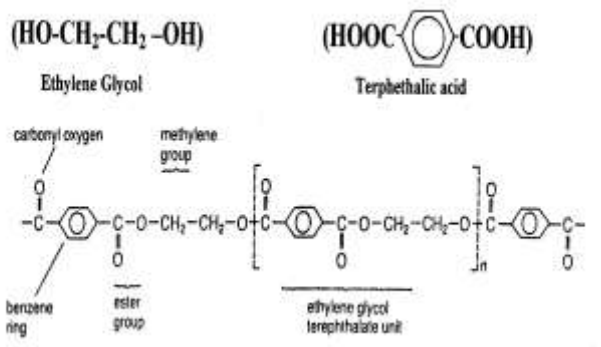


Figure (8) (a–d): Scanning electron microscope photographs (×2000) of the exposed polyester fabrics at different treatment conditions(a),(b), (c) and (d), where, image (a): blank untreated polyester fabric, image (b): polyester sample treated with nanosilver solution with concentration of 50 ppm, image (c): polyester sample treated with plasma using argon gas, and image(d): polyester sample treated with plasma at argon gas medium then treated with nanosilver solution with concentration of 50 ppm.

Surface Elemental Analysis:

Table (4) shows the changes in carbon, hydrogen and nitrogen percentages for plasma treated polyester samples in a medium of argon or nitrogen gas using the optimum conditions that last obtained from the optimization part of this search. The results demonstrated that the carbon percentage increased by about 0.087% in plasma/N_2 treated polyester but increased by 0.23% for plasma/Ar treated polyester. These results also showed that the hydrogen percentage increased by about 25.8% in plasma/N_2 treated polyester but increased by only11.33% for plasma/Ar treated polyester. The nitrogen percentage appeared only in case of plasma /N_2 treatment of polyester. These results can be explained in view of the chemical structure of polyester polymer as shown below, which showed that polyester has a hydrocarbon skeleton [18] .



A section of polyester polymer

Antibacterial properties:

The antibacterial activity of all examined polyester fabrics was evaluated after the specified contact time (24 h) and it is calculated by measuring inhibition zone against the growth of Staphylococcus aureus and Escherichia coli, where the Staphylococcus aureus is a gram-positive pathogenic microorganism causing many diseases[19] such as toxic shock, purulence, abscess, fibrin coagulation and endocarditis, while Escherichia coli is a gram-negative microorganism .Table (5) demonstrates these results of antibacterial properties.

These results showed that increasing the concentration of nanosilver resulted in more reduction of both bacteria. However, the combination of nanosilver and plasma treatment of polyester fabrics showed very good activity against Staphylococcus aureus even by applying low content of nanosilver particles (25 ppm). These results can be explained [20], where, silver is a safer antibacterial agent in comparison with some possible organic antibacterial ones that have been avoided because of the risk of their harmful effects on the human body. Using silver nanoparticles may lead to increasing the number of particles per unit area on the treated surface and, thus, antibacterial effects can be maximized [21].

Conclusion

This article had focused on studying the feasibility of the application of DC plasma discharge and or/ nanosilver treatments to poly (ethylene terephthalate) fabrics , with the concern of the effect of three different treatments , plasma pretreatments (using Ar or N_2 gas as a carrier) ,nano silver with different concentrations , and finally combined plasma pretreatments(best conditions) with nanosilver treatments. The work extended to evaluate the effect of these applied treatments on the performance of polyester fabrics on: air permeability, water absorbency, mechanical properties, electron spin resonance spectroscopy (ESR), fiber surface morphological changes, and antibacterial activity. The reported results showed that the wet-ability of the treated polyester samples was increased by increasing either the current or the time at the treatment pressure. Also, it increased with increasing pressure. The plasma /argon or N_2 treatment of polyester resulted in a significant improvements in the water absorbance of these samples. The results also showed that the use of plasma is safe and does not cause drastic deterioration in the mechanical properties of the fabrics. Finally, the SEM results showed that plasma and or nanosilver treatment of polyester resulted in swelling of the fiber surface polyester with the appearance of some nodes on their surface. This effect may be enhanced in using plasma exposure followed by nanosilver treatment of polyester with high performance.

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Table (1): The change in air permeability and water absorption values of plasma treated polyester samples in a medium of argon or N_2 gas at different exposure times.

Plasma exposure time* (sec.)	Air- permeability (cm^3/cm/S)		Water absorption (sec.)	
	Plasma/Ar gas[a]	Plasma/N_2 gas[b]	Plasma/Ar gas[a]	Plasma/N_2 gas[b]
0	9.802	9.802	32.494	32.494
15	10.98	11.04	30.818	29.714
30	11.76	11.28	24.754	27.976
45	11.30	11.56	25.716	22.116
60	11.06	11.30	35.644	32.844
120	10.44	9.506	37.222	36.022

(a) Conditions of plasma/Ar-treatment were: current: 75 mA, pressure: 0.3 Torr, and distance: 8 cm
(b) Conditions of plasma/N2- treatment were75 mA, pressure: 0.2 Torrand distance: 6 cm.

Table (2) Time: The change in air permeability and water absorption values of plasma treated polyester samples in a medium of argon or N_2 gas at different plasma exposed current

Applied Current	Air- permeability(cm^3/cm/S)		Water absorption (sec.)	
	Plasma/ Ar gas*	Plasma /N_2 gas**	Plasma/ Ar gas*	Plasma/ N_2 gas**
Blank	9.802	9.802	32.494	32.494
40	9.994	9.976	28.525	29.852
50	11.03	10.66	27.254	27.746
60	12.14	11.34	24.538	24.252
75	12.63	11.58	20.18	20.676
90	10.38	11.08	32.346	31.50

* Conditions of the plasma/Ar- treatment were: current: 40 – 50 – 60 – 75 - 90 m.A. pressure 0.4 Torr. time: 30 Sec. distance: 8 cm
** Conditions of the plasma/N2- treatment were: current: 40 – 50 – 60 – 75 - 90 m.A., pressure 0.4 Torr. : 45 Sec. distance: 6cm

Table (3): The change in air permeability and water absorption values of plasma treated polyester samples in a medium of argon or N_2 gas at different hydrostatic pressures

Plasma Applied pressure* (Torr.)	air permeability values ($cm^3/cm/S$)		water absorption values (Sec.)	
	Plasma Ar gas*	Plasma N_2 gas**	Plasma Ar gas*	Plasma N2 gas**
Blank	9.802	9.802	32.494	32.494
0.2	9.926	10.45	30.214	31.244
0.3	10.096	10.86	29.098	29.84
0.4	10.848	11.50	22.584	22.343
0.6	9.492	11.44	25.672	23.486

**Conditions of plasma/Ar- treatment: were; current: 75 m.A, pressures: 0.2 – 0.3 – 0.4 – 0.6 Torr. time: 30Sec.distance: 8 cm*

***Conditions of plasma/N2- treatment: were; current: 75 m.A, pressures: 0.2 – 0.3 – 0.4 – 0.6 Torr. time: 45Sec.distance: 6 cm*

Table (4): The changes in C, H, N % of plasma treated polyester samples in a medium of argon and nitrogen gas using the optimum conditions

Sample name	C %	H %	N%
Blank polyester	68.97	5.03	0.0
plasma treated polyester samples/N_2	69.03	6.33	1.9
plasma treated polyester samples/Ar	69.13	5.6	0.0

Table (5): Antibacterial properties of the examined samples

	Examined samples				
Name of Bacteria	Blank (1)	Blank polyester + plasma (2)	25ppm* (4)	25ppm +plasma (5)	25ppm*+ plasma (6)
Escherichia coli	0	0	1.7	2.4	3.0
Staphylococcus aureus	0	0	1.5	2.2	2.9

	Examined samples				
Name of Bacteria	Blank (1)	Blank polyester + plasma (2)	50ppm* (4)	50ppm + plasma (5)	50ppm*+ plasma (6)
Escherichia coli	0	0	2.2	2.7	3.9
Staphylococcus aureus	0	0	2.0	2.4	3.7

1)-Blank = Blank polyester fabrics did not treated with any treatments.2)-Blank +plasma = blank treated with only plasma.3)25 ppm &50 ppm = samples treated with only nanosilver with out certain conditions or plasma.4)25 ppm*& 50 ppm* = samples treated with nanosilver in certain conditions with out plasma. 5)25ppm + plasma & 50ppm + plasma = samples treated with nanosilver and plasma with out certain conditions. 6)25ppm* + plasma & 50ppm* + plasma = samples treated with nanosilver and plasma in certain conditions.