

# Influence of Plasma Surface Activation and SnO<sub>2</sub>NPs Adsorption on the Properties of Polyester, its Cotton Blend and Polyamide Fabrics

Shalaby S.E.\*<sup>1</sup>, Abo El-Ola S. M\*<sup>2</sup>, Al-Balakocy N.G.\*<sup>3</sup>

<sup>1</sup>Protenic and Manmade Fibers Department, National Research Centre (NRC), Scopus Affiliation ID: 60014618, Textile Research Division, Dokki, Cairo, Egypt.

Correspondence Author: Shalaby, S. E., E-mail: samyshalaby40@yahoo.com

<sup>2</sup>Protenic and Manmade Fibers Department, National Research Centre, Textile Research Division  
<sup>2</sup>Dokki, Cairo, Egypt. samiham\_2000@yahoo.com

<sup>3</sup>Protenic and Manmade Fibers Department, National Research Centre, Textile Research Division  
<sup>3</sup>Dokki, Cairo, Egypt. nasergad@yahoo.com

**Abstract-**The objective of this research was to impart additional values on PET, PET/C blended and Nylon-6 fabrics such as antistatic, antimicrobial and ultraviolet protection (UPF) properties. Tin dioxide nanoparticles (SnO<sub>2</sub>NPs) were incorporated by chemisorptions into the fabrics previously pretreated by a dielectric barrier discharge (DBD) to create COOH and OH groups on the fabrics surfaces which enhanced the attachment of SnO<sub>2</sub>NPs from solution dispersion onto fabrics surfaces. The changes of morphology of the fabrics surfaces after treatment and the evidence of the presence of tin oxide were confirmed by scanning electron microscope coupled to elemental analysis. In addition antistatic, antimicrobial properties of the treated fabric (against *B. Mycoide*, *E. Coli* and *C. Albicans*) and ultraviolet protection were evaluated. X-Ray diffraction (XRD) and Fourier Transformed Infrared Spectroscopy (FT-IR) were used to follow the changes of the fabrics properties.

**Key words** - PET, PET/C, Plasma, Tin Dioxide, Antistatic, Antimicrobial, Ultraviolet Protection, XRD, SEM, EDX.

## I. INTRODUCTION

Manmade fibers such as PET and PA-6 are characterized by accumulation of static charges on their surfaces compared with natural fibers [1]. The phenomenon of charging occurs as a result of rubbing the fabric surfaces, which lead to creation of positive charges on one surface and negative charges on the second one. All these charges on the fabric surfaces make the consumer annoyed as well as the fabric will suffer from dusting problem as a result of attracting the suspended dust in the air.

Surface modification of polyester and Nylon is required to improve their wettability and adhesion characteristics. Chemical processes applied on the wet processing line in dyeing and finishing textile sectors accompanied by consumption, pollution of water resources and drying the processed fibers used a lot of energy and time so the cost is high [1].

The improvement of the antistatic properties of manmade fibers using nanotechnology (nano-sized titanium dioxide, zinc oxide [2-4] was conducted. It was reported that TiO<sub>2</sub>, ZnO provide antistatic effects because they are electrically conductive materials. Such materials dissipate effectively accumulated static charge on the fabric surface. On the other hand, plasma improves antistatic properties; as it creates reactive groups which absorb water and moisture in the air [5].

Surface modification of final properties of manmade fibers is very important, ultimately imparting new properties to textile product, for example providing synthetic fibers UPF and antimicrobial properties as well as improves the electrical conductivity. DBD plasma is one of the most interesting and attractive approach for this purpose [6].

Dielectric Barrier Discharge DBD is one of atmospheric pressure non equilibrium plasma sources which are used in treatment of synthetic fabrics [7]. Atmospheric plasma treatment is a more economical and ecological pretreatment process, was performed to enhance the interactions in the interfaces by combination of plasma induced increase in bonding surfaces such as micro pitting or mechanical interlocking [8]. It was reported that plasma treatment used for improving the static build up and dissipation, and moisture transport and comfort, wettability and adhesion so the antistatic ability of the fibers is drastically enhanced by plasma treatment [1].

Because of tin dioxide films are semiconductors, high transparency and very good electrical conductivity, they used as a window layer, heat reflectors in solar cells. Also these films are chemically inert, mechanically hard and can resist high temperature [9].

Few published articles concern with employment of SnO<sub>2</sub> as reduce the electric static charge of synthetic fibers. In the present work combining the advantages of plasma surface activation and nanoparticles adsorption to achieve the best performance for PET ,its cotton blend and Nylon, plasma based surface modification has been developed for PET , its cotton blend and nylon fabrics in order prepare surface for further tin oxide nanoparticles adsorption where as surface has relevant number of active sites able to attract nanoparticles, to enhance the fabric properties such as the electrical properties, antimicrobial as well as the resistance to UV.

## II. EXPERIMENTAL WORK

### A. Materials

#### 1. Fabrics

Polyester (PET), and polyester / Cotton blend (PET/C 50/50) fabrics used throughout this study were, woven fabric cloth made from filament yarns. They were kindly supplied by Misr polyester Co., Kafr EL-Dwar, Egypt. The fabrics were scoured at 80°C for 45 min. with solution containing 2 g/L nonionic detergent, washed with cooled water, squeezed, and finally air dried.

Nylon-6 fabrics used throughout this study were in the form of filament knitted fabric cloth made from filament yarns (warp 42 ends/cm, weft 36 picks / cm) was kindly supplied by El-Nasr (Shourbagy) Co., Cairo, Egypt . The fabrics were scoured at 80°C for 45 min. with solution containing 2 g/L nonionic detergent, washed with cooled water, squeezed, and finally air dried.

#### 2. Chemicals

Tin dioxide is nano-powder <100 nm. Purchased from Sigma - Aldrich of pure analytical grade were used without any further purification, Sodium hydroxide, is analytical grade chemicals.

#### 3. Microorganisms

*Bacillus mycoides* (B.m) (Gram positive bacterium), *Escherichia coli* (E.c) (Gram negative bacterium), and *Candida albicans* (C.a) (nonfilamentous fungus) were used for estimation of antimicrobial potency of control and finished samples. Microorganisms were obtained from the culture collection of the Department of Microbial Chemistry, Division of Genetic Engineering and Biotechnology, National Research Centre of Egypt. Modified nutrient agar medium was used and is composed of the following ingredients (g/L): peptone (10.0), beef extract (5.0), NaCl (5.0), and agar (20.0). The pH was adjusted to 6.8. This medium was sterilized for 20 min at 121°C under pressure.

### B. Methods

#### 1. Preparation of SnO<sub>2</sub> NPs

0.1-1.0 gr of SnO<sub>2</sub> NPs < 100nm was added in 100 ml of distilled water under vigorous stirring, Non ionic detergent was employed as dispersant agent to enhance the stability of the suspension.

#### 2. Plasma Surface activation of Fabrics

Polyester, its cotton blend and Nylon-6 knitted fabrics of 10 cm diameter were firstly exposed to DBD plasma at constant discharge conditions (electrode gap distance 3cm, plasma treatment time 10 minutes, input voltage 3W, input frequency 50Hz, electric current 1.5mA), and under air gaseous environment.

#### 3. Deposition of tin dioxide nanoparticles on the surface of activated fabric

Activated polyester, its cotton blend and Nylon-6 knitted fabrics were immersed in the SnO<sub>2</sub>NPs dispersion solution, the samples were then squeezed to remove the excess dispersion, and dried in air at 22°C (laboratory temperature) for 24 hours and then drying at 100°C for 15 minutes, and then the samples cured in an oven at 130°C for 15 minutes. In order to evaluate the SnO<sub>2</sub>NPs adhesion to the fabrics, the treated fabrics were washed three times according to a standard method AATCC Test Method (61-1989).

### C. Analysis

#### 1) Carboxylic content

Carboxylic content was determined according to the method described by [10].

#### 2) SEM and EDX

Surface structure and the morphology of all fabric samples characterized by a JEOL-Model JSM T20 scanning electron microscope (SEM), operating at 19 kV was used to obtain photomicrographs of fabrics surfaces. Gold layer was deposited on the samples before analysis.

#### 3) XRD

PAN Analytical EMPYREAM 2 (Netherland) with Cu radiation ( $\lambda = 1.5406\text{\AA}$ ) as the x-ray source, the lab operated at 45 KV and 30 mR, 2Q = 10-60, step size = 0.026, step time 20 sec/step. The measurements were carried out in 2 $\theta$  range of 18-33 ( $\theta$  being the angle of Bragg's diffraction), using a Cu radiation of wavelength  $\lambda = 1.5406\text{\AA}$ .

#### 4) FT-IR

The chemical structure was determined using the Fourier transformation infrared (FT-IR) spectrometer, model NEXUS 670, NICOLET USA. The measurements were carried in spectral range from 4000 to 500 cm<sup>-1</sup>. Reflection percentage measurement technique was applied (R %) to all investigated samples.

### 5) Antimicrobial Properties

Antimicrobial activity of PET and PET/C, and Nylon-6 fabrics loaded with SnO<sub>2</sub> NPs was quantified using disk diffusion method. In this method the antimicrobial potency by diffusion was quantified by measurement in millimeters of the width of the zone of growth inhibition around the sample according to AATCC standard test method.

### 6) Electrical Properties

The Direct Current (D.C.) was used, Electrical Resistance (R) Ω, Resistivity (ρ) Ω Cm, and Electrical Conductivity (1/ρ) Ω<sup>-1</sup> Cm<sup>-1</sup>] have been studied using the computerized LRC Bridge (Hioki Model 3532 – 50 LCR Tester). The fabric samples were in the form of tablets. The thickness and diameter of the samples under investigation was measured.

### 7) UPF factor

UPF factor was measured using UV-Shimadzu 3101 P C - Spectrophotometer. It is a double beam direct ratio measuring system. It consists of the photometer unit and a pc computer. UPF factor was determined according to the method described in Australian/New Zealand standard AS/NZS 4399: 1996. UPF values were calculated automatically and classified according to table A.

TABLE (A). Protection and Classification According to AS/NZS 4399:1966

UVP	UPF
Excellent	40,45,50,50+
Very good	25,30,35
Good	15,20
Non-Rateable	0,5,10

## III. RESULT AND DISCUSION

### Effect of Surface Plasma Activation on Carboxylic Content

DBD Plasma treatment in presence of air provides polar functional groups on the textile surfaces such as C-O, C=O, O=C-O, which alter the surface energy of polymers and enhances attachment of metal oxides nanoparticles [11, 12]. These results were elucidated practically by determination of the carboxylic groups before and after the activation process. It was found that, the carboxylic content increased from 2.95 to 38.50 meq/100 gr fabrics in case of polyester, while in case of polyester cotton blend the carboxylic content increased from 5.0 to 43.2 as a result of applying plasma treatment. Nylon-6 blank shows that 10.21 meq/100 gr fabric, while activated one has 46.9 meq/100 gr fabric as shown in (Table 1).

DBD plasma treatment increases the numbers of polar groups containing oxygen on the fabric surfaces which gives them the ability to incorporate with the moisture through hydrogen bonding.

TABLE I. The Amount of SnO<sub>2</sub> NPs\* Loaded on PET, PET/C and Nylon 6 Fabrics Activated with Air Plasma.

Fabrics	Carboxylic Content (meq/100 gr. Fabric)	The Amount of Sn* Estimated By EDX (Atomic %)
PET Blank→SnO <sub>2</sub>	2.95	0.10
PET→ Plasma→SnO <sub>2</sub>	38.43	0.18
PET/C Blank→SnO <sub>2</sub>	4.99	0.06
PET/C→ Plasma →SnO <sub>2</sub>	43.12	0.25
Nylon Knitted Blank→SnO <sub>2</sub>	10.21	0.0
Nylon → Plasma →SnO <sub>2</sub>	46.90	0.04

### Plasma Treatment Conditions:

Electrode Gap Distance, 3 mm.; Treatment Time, 10 min.; Power, 3 w; Frequency, 50 HZ; I, 1.5 mA.

### Sol-gel Treatment Conditions:

[SnO<sub>2</sub>], 1.0%; Curing Temperature, 150°C; Curing Time, 30 min.

\* After Three Washing Cycles According to AATCC Test Method (61-1989).

### Deposition of Tin oxide Nanoparticles on the Surface of Activated Fabric

#### Characterization of Modified Fabrics with SnO<sub>2</sub> NPs

The characterizations of the finished PET, PET/C blend and Nylon-6 fabrics were carried out through SEM, FTIR and XRD, electrical and antimicrobial properties.

#### Morphology (SEM and EDX)

The surface morphology of the modified fabrics has been evaluated after the treatment has been evaluated by scan electron microscope. Figure (1) shows that the neat fabrics shows smooth fabrics (Figures 1a

and 1e) while the modified fabrics are characterized by a coarse surface due to adsorption of tin oxide. The micrograph of modified fabric showed that, heterogeneous distribution of SnO<sub>2</sub> NPs onto the fabric surface (agglomerated or unlevel distribution).

Atomic % estimated values by EDX could be used as a useful factor to understand the disruption and surface density of SnO<sub>2</sub> NPs thin film of modified coated fabrics. Tin signal has been observed for all modified fabrics proving that the plasma activated fabrics to adsorb SnO<sub>2</sub> NPs onto the surfaces.

Figure (1) shows the detection of SnO<sub>2</sub> NPs particles by EDX on the modified PET and Nylon-6 fabric surfaces. From these spectra, we can conclude that the deposition of Sn, even after three washing cycles (15 home washing cycles) on the PET and Nylon-6 fabrics surface (Table1), which means that SnO<sub>2</sub> NPs have sufficient adhesion towards the activated PET ,its cotton blend and Nylon-6 fabrics.

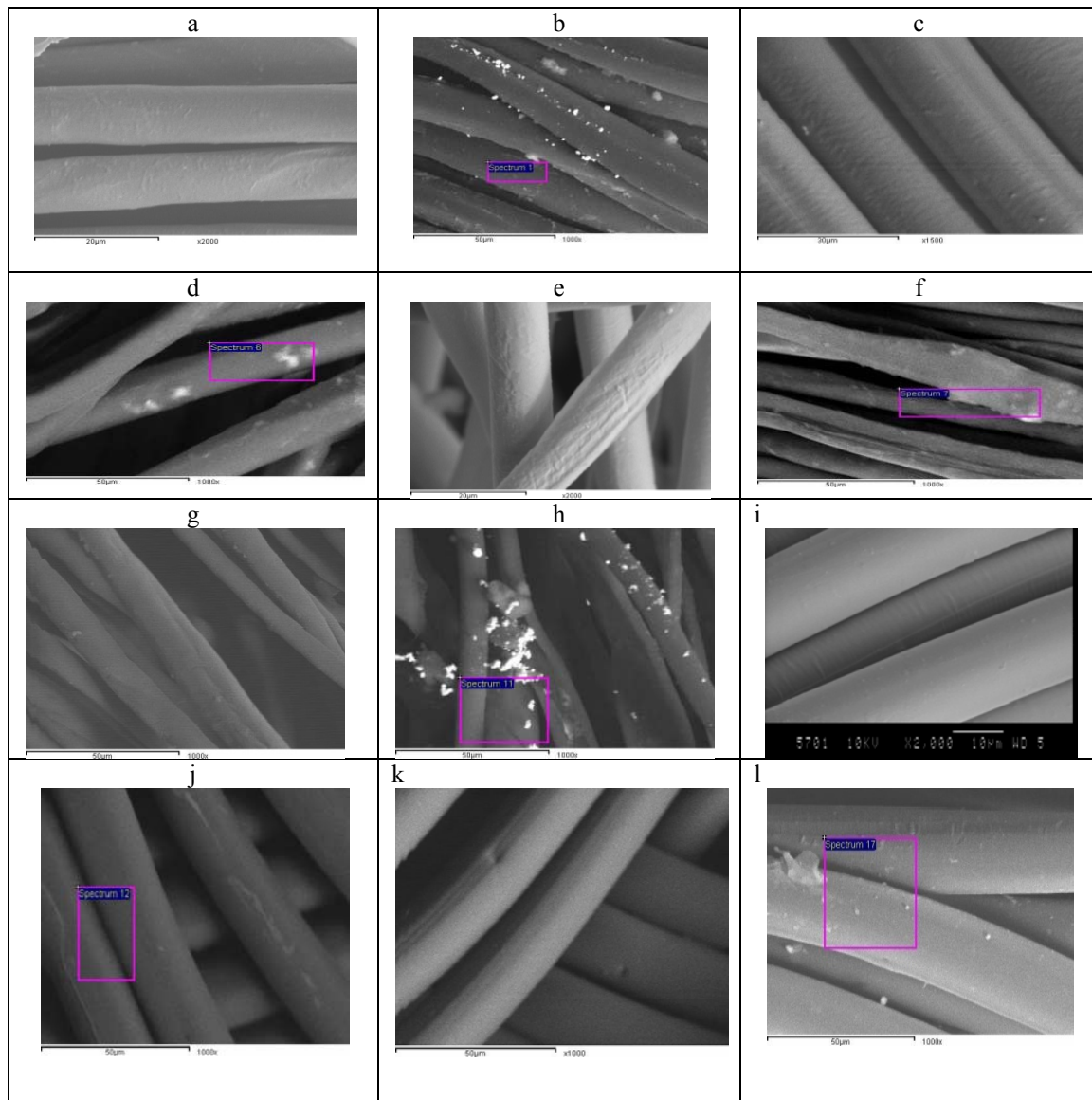


Fig. 1. SEM and EDX Micrographs of the Fabrics Activated with Air Plasma and Loaded with SnO<sub>2</sub> NPs\* (1000x)  
 (a) PET Blank (b) PET Blank→SnO<sub>2</sub> (c) PET\* (d) PET\*→SnO<sub>2</sub> (e) PET/C Blank (f) PET/C Blank→SnO<sub>2</sub>  
 (g) PET/C\* (h) PET/C\*→SnO<sub>2</sub> (i) Nylon Knitted (j) Nylon Knitted→SnO<sub>2</sub> (k) Nylon Knitted\* (l) Nylon Knitted\*→SnO<sub>2</sub>  
 \*plasma activation \*\*After Three Washing Cycles According to AATCC Test Method (61-1989).

### FT-IR

Activation by DBD plasma makes significant changes in the chemical structure of the PET, PET/C and Nylon-6 fabrics surfaces. Figure (2a) of parent polyester fabric shows absorption bands at 1649-1712, 3408-3388, and 2317  $\text{cm}^{-1}$ , which are matched to C=O, O—H, and C—H stretching respectively. Figure (2e) of parent Nylon-6 fabric shows absorption bands at 1662–1531, 3083, and 2920–2852  $\text{cm}^{-1}$ , which are matched to C=O in CONH, NH<sub>2</sub>, N—H stretching and C—H stretching respectively.

The spectrums of modified PET and PET/C fabrics activated with plasma (Figures 2d, 2h) showed new bands at 847 and 689  $\text{cm}^{-1}$  respectively, which can correspond to Sn—O. While in case of plasma activated Nylon-6 fabrics and modified with SnO<sub>2</sub>NPs (Figure 2j) new bands appeared at 585  $\text{cm}^{-1}$  and 794  $\text{cm}^{-1}$  as well as 868  $\text{cm}^{-1}$  respectively, which can correspond to Sn—O.

These bands can support the hypothesis of ionic character of the new band formed due the loading of SnO<sub>2</sub>NPs on plasma activated fabrics. This result agrees with similar finding [13]. During this study we found that only activated surfaces were able to fix SnO<sub>2</sub>NPs from dispersion solutions.

### X-ray Diffraction Measurements

The fine structure of modified SnO<sub>2</sub> NPs PET and Nylon-6 fabrics was studied by XRD technique. From the data represented in Table 2, it can be suggested that:

1- polyester fabrics have the same diffraction patterns with three peaks at  $2\theta$  17.5°, 22.5° and 26.0° whereas Nylon-6 fabrics have the same diffraction patterns with two peaks at  $2\theta$  20.3° and 23.6°.

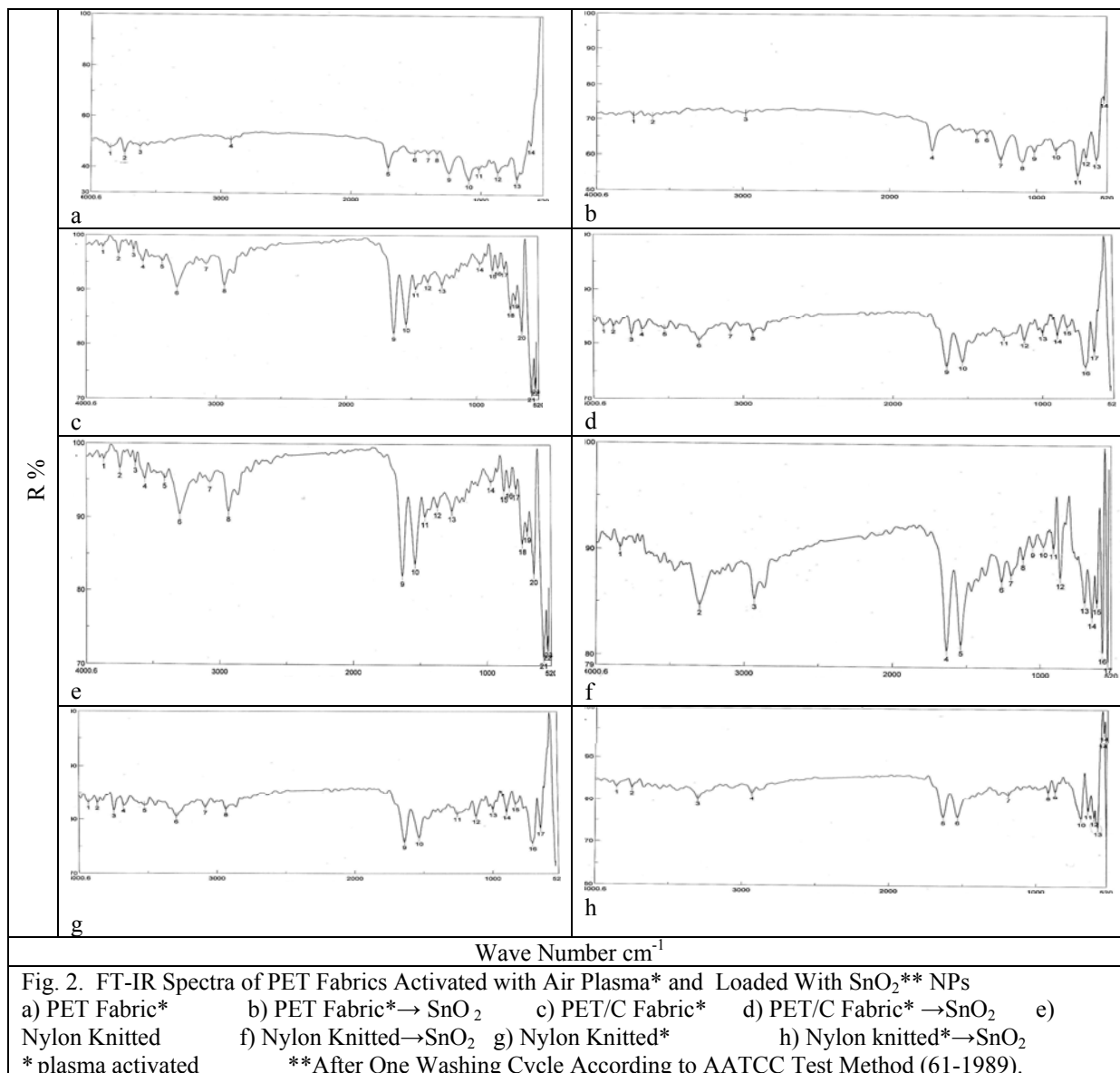
2- No individual peaks characteristic to SnO<sub>2</sub>NPs phase in the range of  $2\theta$  (25° to 45°) for modified samples under investigation. This may be render to the ionic interaction of SnO<sub>2</sub> with COOH groups of activated surfaces. As mentioned previously by FT-IR analysis.

3- The peaks intensities of the modified PET and Nylon-6 fabrics became weaker compared to those of the parent fabrics. The presences of SnO<sub>2</sub>NPs on fabric surfaces were shielding the X-ray beam, so the modified fabrics peaks appeared weaker.

4- The inter-planer spacing and  $2\theta$  values for all the modified fabrics under investigation have minor changes.

5- The full width at half maximum modified fabrics peaks is broader than parent one (The width of these peaks is a direct indication to quite small particle size of SnO<sub>2</sub>NP) [13]. This may be resulting from the overlapping between peaks of SnO<sub>2</sub> NPs and modified fabrics in the crystalline area.

According to the abovementioned results, it can be suggested that, there are ionic bonds between the positive charges of SnO<sub>2</sub>NPs and partially negative charges fabric due to the presence of COO<sup>-</sup> and C—O<sup>-</sup> groups induced by plasma.



### Electrical Conductivity

Tin has high electrical conductivity among other metals. It was expected, by loading and stabilizing amount of SnO<sub>2</sub>NPs on PET, PET/C blend and Nylon-6 fabrics surfaces, the electrical resistance of the samples decreased (Table 3). An accepted assumption is that a textile material exhibiting a surface resistance of less than  $5 \times 10^9 \Omega$  will not build up enough charging for a spark formation [14]. It was reported that DBD plasma treatment increases the surface roughness and introduces polar groups onto the surface of the fabric. Creation such groups could be formed by reacting with the ambient gas during exposure to low temperature plasma [15-16].

Therefore, the different activation methods used in this study are stabilized SnO<sub>2</sub>NPs on PET and Nylon-6 fabrics surfaces and can be helpful in compensation the electrostatic charges. Investigation of the surface resistance to PET and Nylon-6 fabrics, irrespective the method of activation used shows a certain improvement after application SnO<sub>2</sub>NPs. Furthermore, neither hydrolyzed polyester nor grafted Nylon-6 fabrics lost their electrical properties even after three washing cycles, indicating decreasing the resistivity i.e decreasing the static charge accumulation.

TABLE II. 2θ, d-Spacing, Relative Intensity, and FWHM for PET, PET/C and Nylon Fabrics Activated with Air Plasma\* and Loaded with SnO<sub>2</sub>NPs

Sample	2θ			d-Spacing			Intensity Maximum			FWHM			Degree of Crystallinity %
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	
PET Blank	17.5	22.4	25.8	5.1	4.0	3.5	67.8	69.5	100	1.6	3.0	2.7	41.7
PET Blank→ SnO <sub>2</sub>	17.3	22.5	26.2	5.1	3.9	3.4	52.5	63.3	82.7	2.5	4.0	2.8	41.6
PET *	16.8	22.9	25.9	-	3.8	3.4	67.0	109	108	2.7	4.3	2.7	50.2
PET*→ SnO <sub>2</sub>	16.5	22.7	26.1	5.4	3.9	3.4	58.7	60.5	100	0.8	2.0	2.4	40.1
PET/C Blank	16.5	22.6	25.3	5.4	3.9	3.5	32.6	100	26.5	1.7	1.3	1.4	52.3
PET/C Blank → SnO <sub>2</sub>	16.6	22.6	25.8	5.3	3.9	3.4	29.6	100	19.8	1.7	1.3	2.6	46.1
PET/C *	14.8	22.8	25.6	6.0	3.9	3.4	74.0	335	67	1.5	1.5	3.1	53.1
PET/C *→ SnO <sub>2</sub>	16.7	22.7	25.9	5.3	3.9	3.4	35.6	100	29.2	1.6	1.4	2.7	59.6
Nylon Knitted Blank	20.3	23.6	-	4.4	3.8	-	74.5	100	-	0.9	1.7	-	43.3
Nylon Knitted Blank→ SnO <sub>2</sub>	20.1	23.1	-	4.4	3.8	-	100	87.1	-	1.4	2.0	-	39.6
Nylon Knitted*	20.0	23.5	-	4.4	3.8	-	156	166	-	1.8	2.9	-	40.9
Nylon Knitted*→SnO <sub>2</sub>	20.2	23.6	-	4.4	3.8	-	100	97.0	-	1.6	2.4	-	35.0

\* After Three Washing Cycles According to AATCC Test Method (61-1989).

TABLE III. Electrical Properties of PET, PET/C and Nylon fabrics activated with Air Plasma\* and Loaded with SnO<sub>2</sub> NPs

Fabrics	Resistance (Ω)	Thickness (Cm)	Electrode Area (Cm <sup>2</sup> )	Resistivity ρ (Ω.Cm)	Electrical Conductivity 1/ρ (Ω <sup>-1</sup> .Cm <sup>-1</sup> )
PET - Blank	5.8×10 <sup>9</sup>	0.034	1.5714	2.68×10 <sup>11</sup>	0.37×10 <sup>-11</sup>
PET-blank→SnO <sub>2</sub>	5.7×10 <sup>9</sup>	0.036	1.5714	2.49×10 <sup>11</sup>	0.40×10 <sup>-11</sup>
PET- Plasma → SnO <sub>2</sub>	2.1×10 <sup>9</sup>	0.038	1.5714	0.87×10 <sup>9</sup>	0.11×10 <sup>-8</sup>
PET/C Blank	5.7×10 <sup>10</sup>	0.053	1.5714	1.69×10 <sup>11</sup>	0.58×10 <sup>-11</sup>
PET/C→ Blank→SnO <sub>2</sub>	3.7×10 <sup>9</sup>	0.057	1.5714	1.02×10 <sup>11</sup>	0.98×10 <sup>-11</sup>
PET/C → Plasma→SnO <sub>2</sub>	8.3×10 <sup>6</sup>	0.054	1.5714	2.42×10 <sup>8</sup>	0.41×10 <sup>-8</sup>
Nylon - Blank	6.5×10 <sup>8</sup>	0.033	1.5714	3.1×10 <sup>10</sup>	0.32×10 <sup>-01</sup>
Nylon - Blank→SnO <sub>2</sub>	4.64×10 <sup>7</sup>	0.030	1.5714	2.43×10 <sup>9</sup>	0.41×10 <sup>-9</sup>
Nylon - Plasma→SnO <sub>2</sub>	2.56×10 <sup>6</sup>	0.036	1.5714	1.12×10 <sup>8</sup>	0.89×10 <sup>-8</sup>

\* After Three Washing Cycles According to AATCC Test Method (61-1989).

#### Antimicrobial properties

The antimicrobial activity of modified fabrics was investigated against *B. m.*, *E. c.* and *C. a.* Table 4 indicates antimicrobial resistance of fabrics coated with SnO<sub>2</sub> NPs after DBD surface activation. It is seen that, all fabrics samples showed antimicrobial activity against the tested microorganisms. The inhibition zones of plasma treated samples of all fabrics are larger than that for untreated one whereas blank samples have no antimicrobial activity.

#### Ultraviolet Protection Properties

The effect of modification was evaluated against UV. The rate of UV protection was quantified and expressed via UPF values that are given in Table 5. It was found that the UPF factors for parent PET, PET/C, and nylon fabrics are equal to 15.7, 10.1, and 2.3 respectively. The suggested modified approach in this study led to an enhancement in UPF rating to the level of 50+ which mean maximum UV protection. It was found that; a slightly decrease in UPF values for polyester and polyester cotton blend fabrics after three washing cycles. These results suggested excellent laundering durability. Meanwhile, this approach is not suitable for protection Nylon-6 against UV.

TABLE IV. Antimicrobial Activity of PET, PET/C and nylon knitted Fabrics Activated with Air Plasma and Loaded with SnO<sub>2</sub> NPs, Determined by Diffusion Method

Fabrics	Inhibition zone diameter* (mm) :		
	<i>B. mycoide</i>	<i>E. coli</i>	<i>C. albicans</i>
PET blank	-ve		
PET Blank → Plasma	-ve		
PET → Plasma → SnO <sub>2</sub>	11	12	11
PET/C blank	-ve		
PET/C blank → Plasma	-ve		
PET/C → Plasma → SnO <sub>2</sub>	20	14	18
Nylon Blank	-ve		
Nylon → Plasma	-ve		
Nylon → Plasma → SnO <sub>2</sub>	11	12	12

Plasma Treatment Condition:

Electrode Gap Distance, 3 mm.; Plasma Treatment Time, 10 min.; Power, 3 w; Frequency, 50 HZ; I, 1.5 mA.

Sol-gel Treatment Condition:

[SnO<sub>2</sub>], 1%; Curing Temperature, 150°C; Curing Time, 30 min.

\* After Three Washing Cycles According to AATCC Test Method (61-1989).

TABLE V. UPF Value\*s of PET, PET/C and nylon knitted Fabrics Activated With Air Plasma and Loaded with SnO<sub>2</sub> NPs

Fabrics	Number of Washing Cycles**:			
	1	3	1	3
	UPF Values		UPF Rating**	
PET Blank	15.7		good	
PET Blank → SnO <sub>2</sub>	19.3	17.7	Good	Good
PET → Plasma	15.7		Good	
PET → Plasma → SnO <sub>2</sub>	48.0	45.6	Ex.	Ex.
PET/ C Blank	10.1		Poor	
PET/C Blank → SnO <sub>2</sub>	14.0	12.9	Good	Good
PET/C → Plasma	10.13		Poor	
PET/C → Plasma → SnO <sub>2</sub>	53.0	50.3	Ex.	Ex.
Nylon Knitted → Plasma	2.3		Poor	
Nylon Knitted → Plasma → SnO <sub>2</sub>	5.2		Poor	Poor

Plasma Treatment Conditions:

Electrode gap distance, 3 mm.; Plasma Treatment Time, 10 min.; Environmental gas, Air; Power, 3 w; Frequency, 50 HZ; I, 1.5 mA.

Sol-gel Treatment Condition:

[SnO<sub>2</sub>], 1.0 %; Curing Temperature, 150°C; Curing Time, 30 min.

\*According to Australia (AS) / New Zealand (NZS) Standard No.4399 (1996).

\*According to AATCC Test Method (61-1989).

#### IV. CONCLUSIONS

To improve the attachment of SnO<sub>2</sub>NPs onto polyester and Nylon-6 fabrics surfaces, the air DBD plasma treatment was applied to create COOH and OH groups on the fabrics surfaces which enhanced the attachment of SnO<sub>2</sub>NPs from solution dispersion onto fabrics surfaces. EDX of modified fabrics shows a distribution of SnO<sub>2</sub>NPs on the polyester and Nylon-6 plasma treated fabrics. FT-IR spectra proved that ionic interaction between positively charged SnO<sub>2</sub> NPs and negatively charged polyester and Nylon-6 plasma activated fabrics. The binding efficiency of the modified fabrics with SnO<sub>2</sub>NPs is higher than the unmodified one as the lower amounts of nano SnO<sub>2</sub> removed from the treated fabrics through the washing process. Then the fabrics loaded with nanoparticles have got reliable washing durability. It was confirmed that loading of the nano SnO<sub>2</sub> on plasma activated fabrics leads to improve the electrical properties of the fabrics even after three washing cycles, indicating their excellent electrical durability. As well as the modified fabrics acquired antimicrobial activity and ultraviolet protection properties. A slightly decrease in UPF values for polyester and polyester cotton blend fabrics after three washing cycles. These results suggested excellent laundering durability. Meanwhile, this approach is not suitable for protection Nylon-6 against UV.



## ACKNOWLEDGMENT

The authors of this article would like to thank National Research Centre (NRC) - Egypt, for funding the project No. 9030102.

## REFERENCES

- [1] Y. Liu, Y. Xiong, and D. Lu "Surface Characteristics and Antistatic Mechanism of Plasma Treated Acrylic Fibers" *Applied Surface Science* 252; pp2960-2966, 2006.
- [2] S.E. Shalaby, S.M. Abo El-Ola, N.G. Al-Balakocy, M.K. Belakova and H. Afify "Effect of surface Activation Method of PET and PET/C Blended Fabrics on its Functional Finishing with TiO<sub>2</sub> Nanoparticles" *Journal of Applied Science Research* 9 (3):pp1731-1742, 2013.
- [3] S.E. Shalaby, N.G. Al-Balakocy, S.M. Abo El-Ola, M.K. Belakova and A.M. Elshafae "Effect of surface Activation Method of Nylon-6 fabrics by Plasma and Grafting With vinyl monomer on its Functional Finishing with TiO<sub>2</sub> Nanoparticles" *Journal of Applied Science Research* 9 (3): pp1743-1753, 2013.
- [4] S.E. Shalaby, N.G. Al-Balakocy, S.M. Abo El-Ola, M.K. Belakova and A.M. Elshafae "Functional Finishing of Polyester and Polyester Blended Fabrics with Zinc Oxide Nanoparticles" *International Journal of Applied Chemistry*, 10, (1), pp77-94 (2014).
- [5] Y.W.H. Wong, C.W.M. Yuen, M.Y.S. Leung, S.K.A. Ku and H.,L.I. Lam "Selected Applications of Nanotechnology in textiles" *Autex Research Journal*, 6 (1), March 2006.
- [6] X. Xia, S. Jiang, X. Li, Q. Wei and X. Dong "Photocatalytic Activity, Surface Morphology, and Mechanical Properties of Atmospheric Plasma-treated HTPET Fiber with SnO<sub>2</sub> Coating" *Journal of Fiber Bioengineering & Informatics* 4:2, pp199-208, 2011.
- [7] Y. Klenk, J. Pichal and L. Aubrecht "Improvement of Polyester Fabric Wettability by Atmospheric DBD" *WDS'07 Proceedings of Contributed Papers, Part II*, pp198-201, 2007.
- [8] G.A.O. Zhi-qiang and Q. I.U. Yi-ping "Surface modification on Polyester (PET) Fabric Treated by Dielectric Barrier Discharges (DBD)" *Journal of Xi'an Polytechnic University* 23 (2), pp 407-412, 2009.
- [9] K. S. Shamala, L.C.S. Murthy and R.A.O. Narasimha "Studies on Tin Oxide Films Prepared by Electron Beam Evaporation and Spray Pyrolysis Methods" *Bull. Mater. Sci.*, 27(3), pp295-301, June 2004.
- [10] G. Daul, R. M. Rinhandt and J.D. Reid, "Preparation of Soluble yarns by the Carboxymethylation of Cotton" *Textile Res J.* 23, p 719, 1953.
- [11] A. Bozzi, T. Yuranova and J. Kiwi "Self-Cleaning of Wool - Polyamide and Polyester Textiles by TiO<sub>2</sub> -Rutile Modification under Daylight Irradiation at Ambient Temperature" *Journal of Photochemistry and Photobiology A: Chemistry*, 172, pp27-34, 2005.
- [12] V. Ilic, Z. Saponjic, V. Vodnik, R. Molina, S. Dimitrijevic, P. Jovancic, J. Nedeljkovic and M. Radetic "Antifungal Efficiency of Corona Pretreated Polyester and Polyamide Fabrics Loaded With Ag Nanoparticles", *Journal of Material Science*, 44, pp3983-3990, 2009.
- [13] K. Qi, J. H. Xin, W. A. Daoud and C. L. Mak "Functionalizing of Polyester Fiber with a Self-Cleaning Property Using Anatase TiO<sub>2</sub> and low-temperature Plasma Treatment" *International Journal of Applied Ceramic Technology*, 4, pp554-563, 2007.
- [14] T. Textor and B. Mahltig, "A Sol-Gel Based Surface Treatment for Preparation of Water Repellent Antistatic Textiles" *Applied Surface Science* 256; pp1668-1674, 2010.
- [15] P. Slepíčka, N. Slepíčkova, L. Stranska and V. Svorcik "Surface Characterization of Plasma Treated Polymers for Applications as Biocompatible Carriers" *eXPRESS Polymer Letters* 7,(6),535,-545, 2013.