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A Comparative Study between the Filamentary and Glow Modes of DBD Plasma in the Treatment of Wool Fibers

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ABSTRACT
In the present research it has been studied the effect of the DBD plasma on the treatment and modification of the surface a printing properities of the wool. Two types of DBD plasma have been investigated namely; the filamentary mode FDBD plasma and the glow mode GDBD plasma to reach the best condition of the treatment. Two discharge cells have been constructed one of them is for the generation of Atmospheric pressure glow discharge APGD and the other is for the generation of filamentary dielectric barrier discharge FDBD plasma. These two cells have the same dimensions except for the type of the dielectric barrier. In the APGD cell the dielectric barrier is a commercial porous fiber while in the FDBD cell the barrier is a Pyrex glass. It has been found that changing the type of the dielectric barriers acquires the discharge different properties. The efficiencies of these two types of discharge in the treatment of the textiles has been examined by treating the wool fabric with these two types of DBD plasma at different conditions of the current and treatment time. The induced changes in wool properties, such as whiteness index, wettability, tensile strength, elongation %, surface morphology, printability and fastness properties, have been investigated. The surface characterization was performed using FTIR and SEM imaging. It has been discovered that GDBD plasma is more efficient than FDBD because of not only its homogeneity but also the high concentration of nitrogen excited species that are the responsible for the surface activation of the textile.
Keywords- DBD plasma, Filamentary mode, Glow mode, printing properties, wool treatment.

I. INTRODUCTION

It is well known that the structure of wool surface introduces a number of problems such as felting shrinkage and its resistivity to dyeing and printing processes. Hwang *et al.* (2005) considered that the plasma is a dry process for the modification of the wool properties since it does not require the use of water or chemicals. El-Khatib *et al*. (2013) stated that the plasma treatment does not involve handling of hazardous chemicals and thus there are no problems of effluents and their treatments. One of the typical plasma techniques is the dielectric barrier discharge (DBD). Molina *et al.* (2002) studied the effect of using dielectric barrier discharge (DBD) on the textile treatment. Wool is composed of 95% of a natural polymer, the keratin. In the outer part, the cuticle, the cells are in the form of scale. Cuticle cells overlap to create a directional frictional coefficient: the scales are moved by water and they have the tendency to close and join together with the typical movement that is proper to have a good textile but it is also producing felting and shrinkage. Environmentally, the dielectric barrier discharge DBD plasma can be used as an effective technique for modifying the surface properties of wool fabric such as its whiteness, wettability, shrinkage, printability, surface morphology, mechanical properties, dyeability, and fastness properties without much alternation to the interior of the fiber. It is believed that DBD plasma is a cheap and clean technology to treat and modify the textile without affecting its special properties.

In this work, two different modes of DBD have been examined to discover the best conditions for modifying the wool fiber properties. These modes are the filamentary mode FDBD and the glow mode GDBD. The main difference of the two modes is the concentration of the seed electron that able to initial sustain the discharge. If the concentration of the seed electrons is low, the discharge is sustained in FDBD mode. Each seed electron accelerates to the instantaneous anode makes an avalanche which is developed to form the streamer. On the other hand if the concentration of the seed electrons is high enough to make small avalanches, these avalanches interferes to prevent any localization of the discharge and in turns prevent the streamer formation. The discharge in this case is sustained in GDBD mode. Porous fiber plays an important role in the increasing the density of the seed electrons. An internal discharge takes place inside the microholes and on the surface of the porous fiber. This internal discharge assists the discharge that provides sufficient seed electrons for the initiation and growth of the glow discharge in the gas between the two dielectric sheets.

The filamentary mode is the most common DBD operational mode. In filamentary DBDs the electrical breakdown starts almost simultaneously at many points of the surface and proceeds with the development of a large number of short-lived microdischarges of about 100 µm radius, each one generated from a streamer breakdown. Due to the short duration of the microdischarges and their small volume in comparison with the entire gas gap, plasma remains strongly non-thermal. Kogelschatz *et al* (1999) observed the multiple current pulses per half cycle when a filamentary discharge occurs. On the other hand, in the glow mode of DBD a uniform region extending uniformly over the whole electrode surface. Some conditions should verify to obtain the glow mode at atmospheric pressure: a high number of seed electrons, an ionization mechanism under low fields, a high value of the dielectric secondary emission coefficient as stated by Massines *et al.* (1998) . The condition to avoid streamers formation is the ability to produce electrons in small electric field in order to avoid a fast growth of electron avalanche. As an intense space-charge is not generated, ions have time to reach the cathode to promote the secondary electrons emission, so an increase of ion density is also necessary. Besides the electron-neutral collisions, metastables species play an important role in promoting ionization by Penning effect. An increase of the ionization and of the number of electrons emitted from the cathode is not sufficient to ensure a glow regime as also the number of electrons remaining in the gas before the occurrence of a new discharge is quite important. As these electrons arrive at the insulator surface under low electric fields, they are slightly trapped: this is the so called memory effect. Massines *et al.* (1998) stated that, the electrons which are released in the next half period enhance the value of secondary cathode emission and thus enhance the probability of obtaining a glow discharge. Garamoon et al. (2011) studied the effect of changing the type and the arrangement of the dielectric barrier on the characteristics of the discharge. They stated that using different types of dielectric acquires the discharge different properties.

II. Experimental Details

1. Plasma Set up

Figure 1 represents a schematic diagram of two discharge cells of the same dimensions except for the type of the dielectric; in the first discharge cell the dielectric is made of Pyrex glass (which is used for the generation of FDBD) while in the other cell the dielectric is made of a commercial porous fiber (which is used for the generation of GDBD). The two parallel metal electrodes in the two cells are made of steel of a square shapes. The dimension of each electrode is 20 cm. The gap distance between the two dielectric is 2 mm. A high voltage transformer (1–10 kV), which generates sinusoidal voltage at a frequency of 50 Hz, was used as an electric power supply to derive the discharge system.

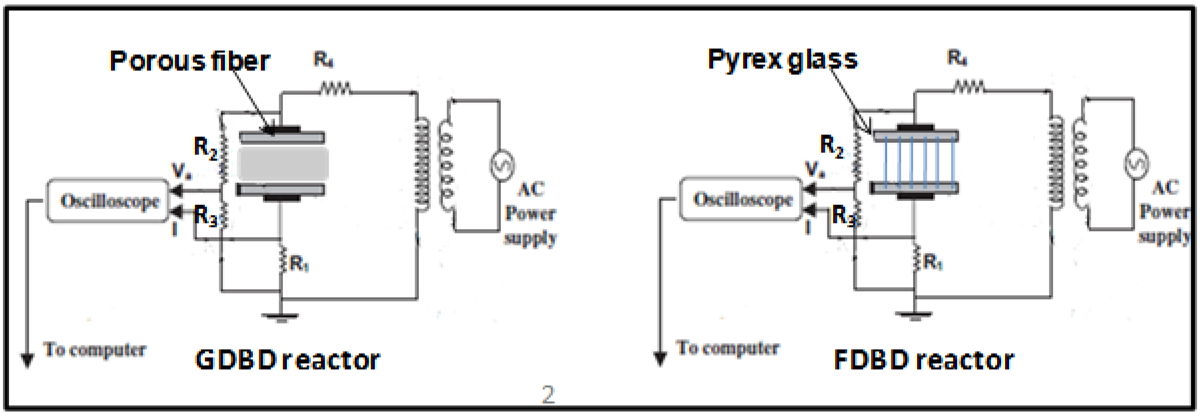

Fig. (1) Schematic diagram of the two discharge cells for the generation of GDBD and FDBD plasma

The discharge was operated in open air under atmospheric pressure. The applied potential difference (Va) across the electrodes and the current (I) passing through the system were recorded using a digital oscilloscope (Regol —100 MHz). The current was measured by the voltage drop across the resistance R1 (=100 Ω) connected in series with the discharge system to the ground as shown in figure 1. The voltage across the two electrodes was measured using the potential divider of the resistance system R2, R3, where R2/R3 = 500. An optical emission spectroscopy (OES) technique consists of a McPherson scanning monochromator [model 270] with a grating of 1200 grooves mm−1 and resolution of less than 2 Å has been used to study the nitrogen spectra in a wavelength range of 300 - 500 nm. The monochromator was then connected to photomultiplier tube (PMT) type 9558 QB, which has a resolution time of less than 1 nanosecond, working at voltage of 1200 volts.

2. The discharge characteristics

2. 1. The voltage - current waveform

Figures 2(a)–(d) represent the voltage and current oscillograms of the FDBD and the GDBD plasmas respectively in air at applied voltages a) 0.85 kV , b) 0.95 kV, c) 1 kV, and d) 1.2 kV respectively. It can be noticed that, at the same applied voltage the discharge current in the FDBD is characterized by short lived filaments of duration about tenth of nanoseconds.

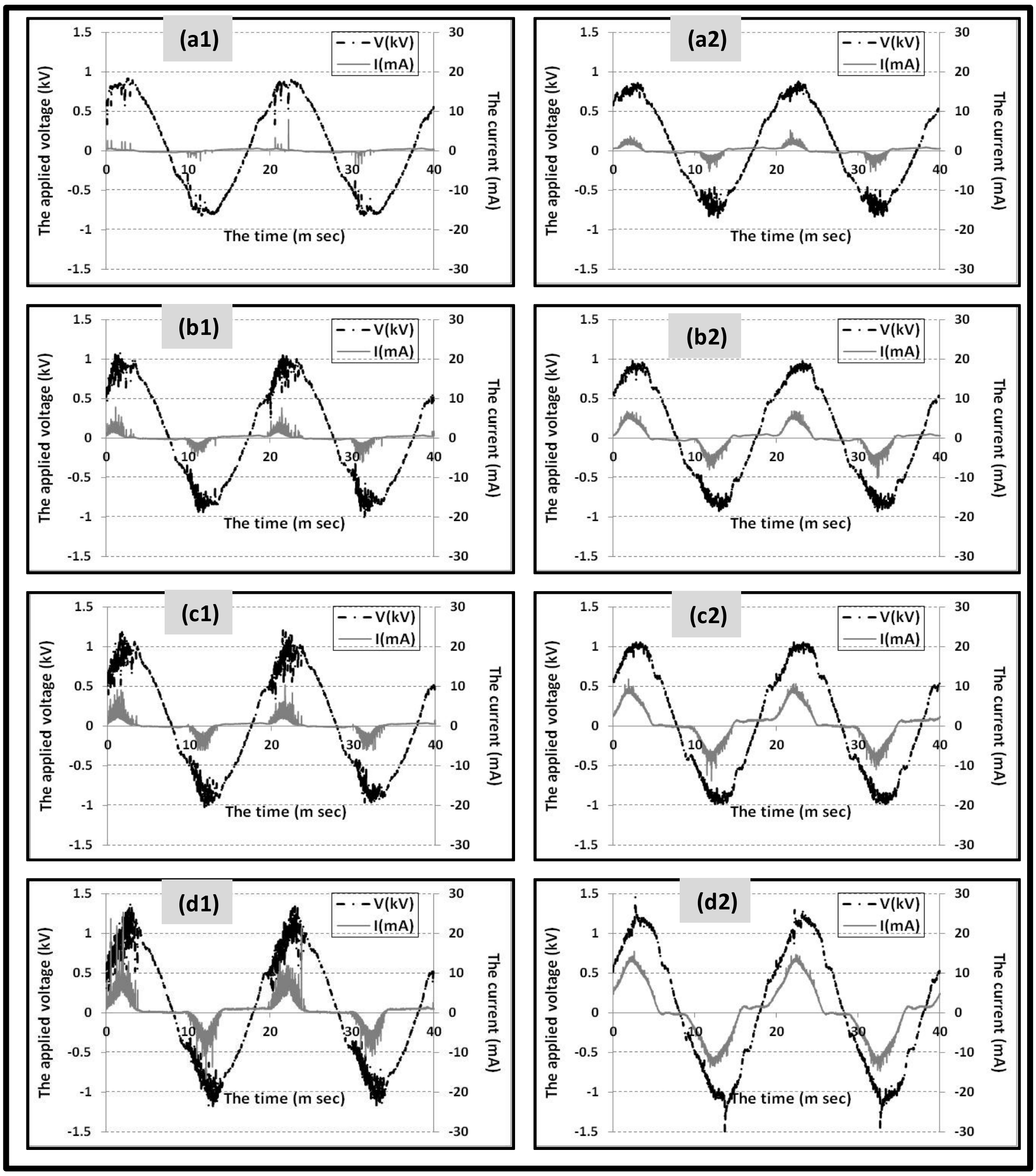

Fig. (2) The voltage –current oscillograms for the FDBD plasma (a1,b1,c1 and d1) and for the GDBD (a2, b2, c2, and d2) respectively at applied voltages ; 0.85, 0.95, 1 and 1.2 kV respectively.

However, the GDBD is characterized by a large hump of duration in milliseconds with small component of microfilaments that are superimposed on the glow component. Garamoon and El-zeer (2009) discovered that using porous dielectric barrier sheets causes the formation of the uniform mode of the DBD that is called GDBD. Because of the special configuration of the porous fiber sheets, which are characterized by the existence of micro holes, an internal discharge takes place inside the micro holes of the porous fiber. Massines and Gouda, (1998) stated that this internal discharge provides seed electrons sufficient for the initiation and growth of the discharge in the GDBD form inside gas between the two porous fiber sheets.

2.2. The consumed power in the discharge cell

The reactor mean power has been obtained by evaluating the area of the parallelepiped that formed from the V-Q traces, which is called Lissajous figure . The area of the Lissajous figure is directly proportional to the consumed energy per one cycle. Figure 3 (a and b) show the Lissajous figure of the FDBD and GDBD reactors respectively at applied voltage 0.8 kV. It can be noticed that the two figures have different area shape. For the FDBD mode the Lissajous figure has smaller area and distorted shape due to the inhomogenity of the discharge and the filamentary formation. On the other hand the Lissajous figure of the GDBD mode is characterized by smoothing and large area which reflect the filamentry free of this mode of discharge. This agrees with the results that stated by Kostov et al. (2009).

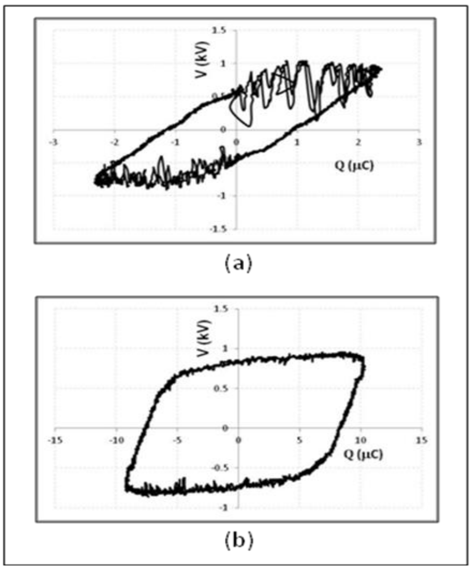

Fig. (3) Lissajous figure of the FDBD and GDBD modes respectively at applied voltage 0.8 kV.

The average consumed discharge power for the FDBD and GDBD reactors are plotted versus the applied ac voltage as shown in Figure 4.

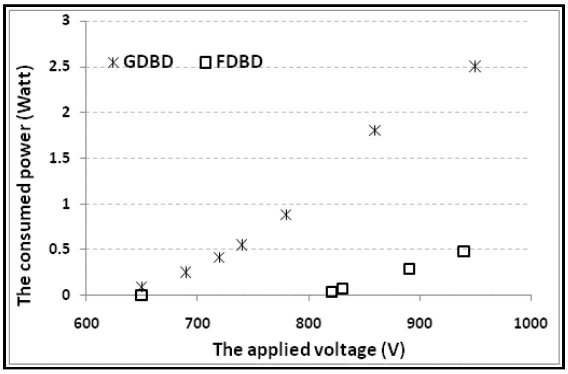

Fig. (4) The average consumed discharge power for the FDBD and GDBD reactors as a function of the applied voltage.

From the figure 4, it can be noticed that the consumed power in the GDBD reactor is greater than that consumed in the FDBD one at the same voltage. This behavior may be related to the large resistivity of the FDBD since the conductivity is due to the displacement current only. However, in the case of the GDBD the conductivity resulted from both the drift and the displacement currents.

2.3. Optical emission spectroscopic (OES) characteristics

Typical emitted spectra of air discharge from the FDBD and GDBD reactors at the same conditions have been observed as shown in Figure 5. The range of the wavelengths is (300-500 nm). The dominant emitted spectra is for the nitrogen second positive system (N2 2P system) bands at wavelengths; 313.6, 337.1, 353.6, 357.6, 375.5, 380.49, 399.8, 405,9 nm that are seen by El-Zeer et al. (2012) in all figures. The nitrogen second positive bands are corresponding to the transition of the nitrogen molecular from the ($C^3\Pi_u$) excited electronic state (ν' = 0-2) to the low-laying ($B^3\Pi_g$) excited state (ν'' = 0-4) according to the following equation that is stated by Kossyi et al. (1992) i.e.:

$$N_2(C^3\Pi_u) \rightarrow N_2(B^3\Pi_g) + h\upsilon$$

The nitrogen first negative systems (N2 1N system) are also observed. It can be noticed that at discharge current I= 4 mA, the intensities are nearly the same for FDBD and GDBD reactors.

However, at I= 7 mA, the peak intensities of all wavelengths increase for the two types of DBD. The wavelength intensities of all nitrogen bands in GDBD plasma are greater than that in the FDBD plasma. This reflects the importance of GDBD in treatment of the textiles than the FDBD plasma. This is due to the high concentration of the nitrogen species in the GDBD reactor which are the main responsible of the surface activation of the wool fabric.

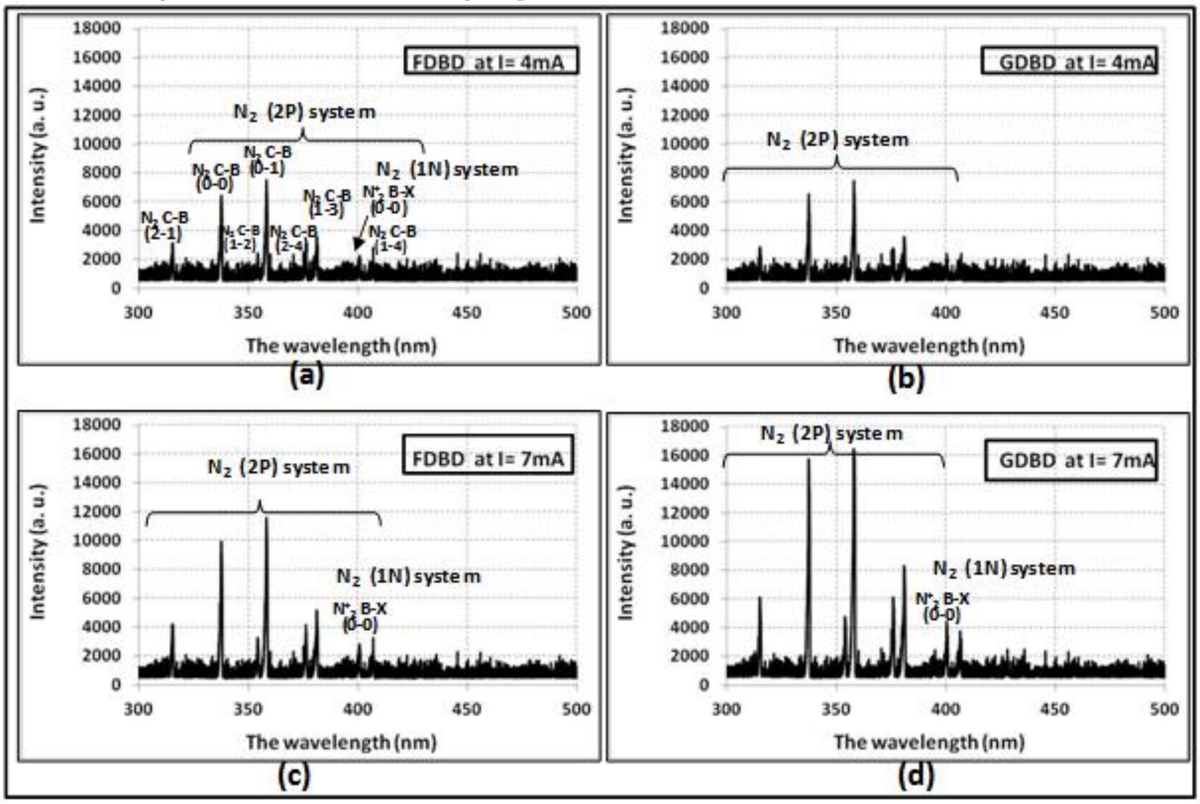

Fig. (5) The typical optical emitted spectra from the FDBD and GDBD reactors at discharge currents I= 4 and 7 mA respectively.

3. Materials

Substrate Wool: (100 %) mill scoured wool fabric, plain wool fabric of 200g/m2 was used in the present study.

Dyestuffs: Suncid Blue N-RH, C.I. Acid Blue 260, supplied from ICI Co., Egypt.

Thickening agent: Guar gum, supplied by Morgan Co. Egypt.

Auxiliaries: Thiourea, urea, ammonium sulfate Scoural CA, non ionic detergent, supplied by Daico company, Egypt, was used for washing process.

4. printing

Wool fabrics were printed with acid dye of special composition. After printing and drying at room temperature, samples were fixed by saturated steam at 105ºC for 30 min. The printing paste formulation which used throughout this study is shown below:

30 gm Acid dye (Suncid Blue N-RH)
50 gm Thiourea
50 gm Urea
5 gm Ammonium sulfate
500 gm Guar gum
X gm water
1000 gmWashing off

The prints were rinsed with cold water and soaped at 50ºC for 15 minutes with 2g/l Scoural CA, then rinsed with hot and cold water and air dried.

5. Measurements

5.1. Whiteness and color strength

The color strength (K/S) and the degree of whiteness of the printed samples were evaluated by Ultra scan pro-spectrophotometer, Hunter Lap, by light reflectance technique. The K/S values of the printed wool samples were automatically calculated according to Kobelka-Munk equation that is stated by (Judd and Wyszecki 1975).

5.2. Scanning Electron microscope (SEM)

The SEM photomicrographs were recorded using JEOL, JXA-840A Electron probe microanalyzer, to study the changes in the surface morphology of plasma treated fabrics.

5.3. Wettability

Water-drop test was applied according to AATCC (2000) test method 39-1980 . The time required for the drop of water to be absorbed into the fabric will be referred to as absorbency values.5.3. Felting shrinkage of wool fabric

A felting shrinkage test was carried out according to the ISO/FDIS 6330 method (IWTO-20-69, 2000) for GDBD-treated, FDBD-treated and untreated fabrics. The washing machine that used was an A-type washer and followed the process of normal TM-31-5A method. Felting area shrinkage Sa (%), was obtained as follows:

$$Felting\ shrinkage\ (Sa)\% = \frac{(OM - FM)}{OM} \times 100 \quad (2)$$

Where OM= original measurements (before felting), FM= The measurements after felting.

5.4. Tensile Strength

The tensile strength test was carried out according to the ASTM (2000) standard test method D1294-95a. On a tensile strength apparatus (model H5KT, Tinius Olsen Company).

5.5. Infrared

Infrared (IR) microscopic analysis was carried out by using Nicolet 380 FT-IR, crystal ZnSe, Thermo electron corporation , using Attenuated total reflection to obtain transmission IR spectra.

5.6. Fastness Properties

The color fastness to washing, crocking, and perspiration, were determined according to the AATCC, (2000) test method 61-1996, AATCC test method 8-1996, and AATCC test method 15-1997 respectively.

III. RESULTS AND DISCUSSION

1. The textile surface properties

1.1 Whiteness

Figure 6 shows the whiteness measurements as a function of the treatment time at discharge currents I= 5 and 10 mA for the FDBD and GDBD respectively. From the two figures it can be noticed that the whiteness behavior takes the same trend after the treatment of the textile by the two modes of DBD plasma.

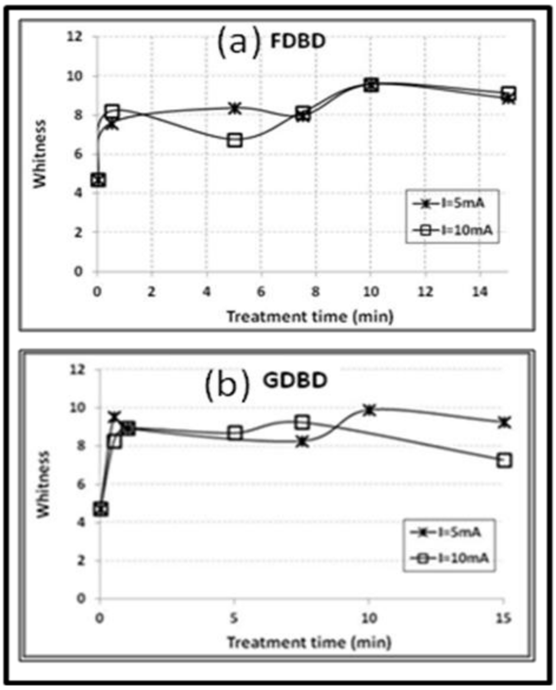

Fig. (6) The whiteness as a function of the treatment time for FDBD an GDBD respectively at I = 5 and 10 mA.

The whiteness increases sharply as it compared by the untreated sample after that it saturates by increasing the treatment time. This behavior is related to the cleaning of the wool surface from any contaminations by the bombardment of the ions and the excited species that are formed inside the plasma reactor.

1.2. Scanning Electron Microscope (SEM)

Figure 7 represents the photos of the surface morphology of the wool fabric that are taken by using scanning electron microscope for the untreated, FDBD and GDBD treated wool samples respectively. The wool samples are treated by FDBD and GDBD plasma at the same conditions ; the treatment time is 10 minutes and the discharge current is 10 mA. From the figure 7(a) it can be noticed that the outermost layer of the untreated wool fibers is the cuticle cells that are overlapped to each other to create a directional frictional coefficient. However, the treatment of the wool by plasma changes the morphology of the wool as it seen in figures 7 (b and c). In the case of FDBD plasma, Figure 7(b), the treated sample were exposed to a nonhomogenuos plasma that consists of locally microdischarges on the surface of the fabric. The local microdischarges that are usually called microfilaments cause a strong local oxidation and etching of the cuticle cells in some regions as it seen in figure 7 (b).

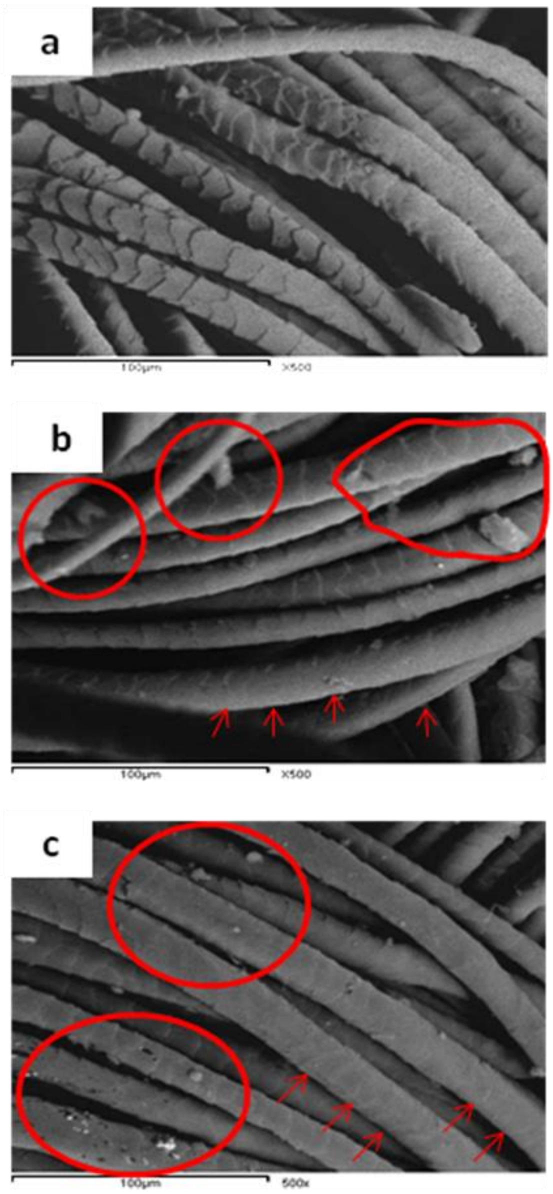

Fig. (7) SEM pictures of a) untreated, b) FDBD treated and c) GDBD treated wool samples respectively.

The etching process removes the scales of the cuticle cells that it makes the fibers of the FDBD treated wool sample seems to be softer than that in the untreated one (represented by arrows). However, the strong oxidation process creates microcracks and microholes in the surface that harms the textile in some cases of the high power plasma. From Figure 7 (c) it can be noticed that the morphology of the GDBD treated wool sample differs from the previous samples. The GDBD plasma is homogeneous and causes the oxidation of the cuticle cells and formation of the microcracks and microholes but the dimensions of the microholes are very smaller than that created in the FDBD. So it doesn't harm the fabric but it improves the wettability of the wool and its absorption of the dye as it will be seen later. Moreover, the etching process makes the fabric softer and free from the scales.

1.3. Wettability

Table 1 represent the wettability measurements using the water drop method for the untreated, the FDBD and GDBD treated wool samples respectively at the same conditions.

Table (1) The wettability, Tensile Strength, Elongation to break % and Area shrinkage % properties for the untreated, GDBD treated and FDBD plasma treated wool samples at different conditions of the current and the treatment time.

Type of plasma	Condition of plasma treatment	Wettability (Sec.)	Tensile Strength of Wool fabric Kg/mm2	Elongation To Break %	Area Shrinkage %
GDBD	Untreated	332.4	32.55	18.23	6.40
	5 mA-7.5 min.	162.6	35.12	19.92	3.98
	5 mA-10 min.	111.6	35.93	21.88	4.94
	10 mA-7.5 min.	123.6	35.62	21.53	4.94
	10 mA-10 min.	93.6	36.66	22.37	3.96
FDBD	5 mA-7.5 min.	112.8	34.45	16.29	4.94
	5 mA-10 min.	95.4	35.40	18.61	4.47
	10 mA-7.5 min.	93.6	35.76	19.05	4.94
	10 mA-10 min.	45	36.00	21.46	4.94

From the results, it can be noticed that the plasma improves the wettability of the wool treated samples irrespective the type of plasma used under the investigation. The wetting time of the untreated sample is 332.4 sec while it reaches about 45 sec for the FDBD plasma treated samples and 93.6 sec for the GDBD plasma treated samples. The wettability improves by increasing the plasma treatment time and also by increasing the plasma discharge current. This behavior was interpreted by Onar and Sarıışık (2005) due to the removing of the highly hydrophobic covalently bound fatty acids surface of the cuticle cells via plasma treatment, the ions and other species in plasma bombard the textile surface and cause an oxidation and a partial removing of the hydrophobic cuticle cells, also the plasma treatment has a strong effect on oxidizing the disulfide bonds of the epicuticle layer and reducing the cross-link density. As a result of this process, the surface of the wool fabric changed to be more hydrophilic. Also hydrophilic groups such as (-COH, - COO, -C=O) will be formed on the surface of fibres as stated by Canal et al. (2007) after the treatment of the wool by air plasma that contains about 20% O2 . The wetting time of the FDBD treated sample is smaller than that of the GDBD treated sample. This may be related to the fact that dimensions of the created voids and microholes in the case of the inhomogeneous FDBD plasma is larger than that created by GDBD plasma.

As a result the large voids can absorb the water drop very quickly.

1.4. The area felting Shrinkage

Felting shrinkage is a mechanism of shrinkage that is confined to wool fabrics and it is a direct consequence of the presence of scales on the wool surface as stated by Saville, (2000). Felting is related to the directional frictional effect (DFE) which is found in wool fibers. The results that shown in the Table 1 represent the area felting shrinkage percentage of the wool fiber for the untreated, FDBD and GDBD plasma treated samples respectively at different conditions of the treatment time and discharge current. It can be noticed that the area felting shrinkage percentage of the wool is decreased from 6.4% to about 4.94% when it was treated by FDBD plasma and to about 3.39% when it was treated by GDBD plasma at the same discharge current 10 mA and treatment time 10 min. This behavior reflects the important effect of the plasma in the reduction of the scales and the directional frictional effect as it was seen by SEM. Moreover, after plasma treatment the fiber is more hydrophilic and then a layer of the water can be formed among the fibers during the washing procedure that reduces their friction and causes felting reduction.

1.5. Tensile strength and Elongation

The effect of plasma treatment on the tensile strength (T.S) and the elongation % (E) to break of the wool fabric has been examined and recorded in the Table 1. Both of the tensile strength and the elongation % to break have been increased when the samples were treated by plasma. This behavior may be related to the etching action of plasma treatment , resulting in a roughening effect on the fibre surface as interpreted by Kan et al. (2004). Such a roughening effect might impart more contact points within the fibers microscopical and yarns macroscopical scale as supposed by Yu W and Yan, (1993). Also the diffusion of nitrogen species that are formed inside the plasma reactor, interstitially among the fabric increases the tensile strength.

1.6. FTIR measurements

Infrared (IR) spectroscopy is a chemical analytical technique, which is mainly used to determine the functional groups in the treated sample. Figure 8 shows a typical IR spectra of untreated, FDBD and GDBD treated wool fabric surfaces.

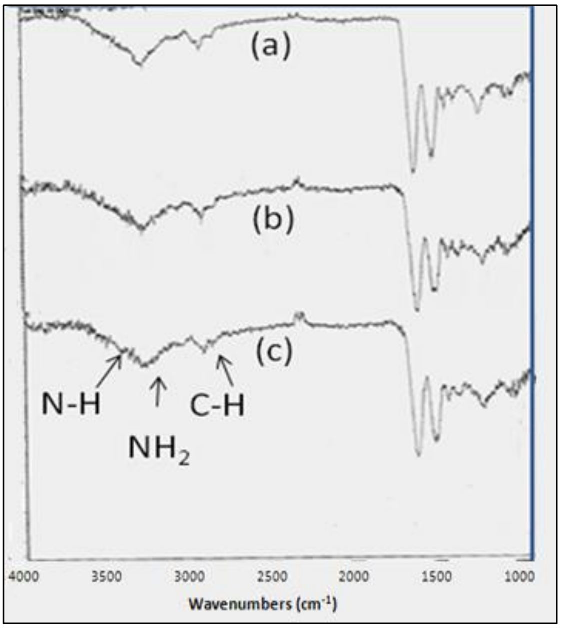

Fig. (8) FT-IR absorption spectra for the untreated , FDBD and GDBD treated wool samples respectively at I= 10 mA and t= 10 min.

It is clear from the spectrum that an oxidation process in the treated sample is occurred. The Oxygen containing groups such as C-O and C=O is obviously observed. This finding indicated that, an air plasma treatment is a high efficient process in incorporating Oxygen on the surface due to the fast reaction between the radical ions and the fabric surface. The produced chemical groups are increased active sites on the treated surface which led to improve its properties. There is a slight increase in the N-H and C-H groups at wave numbers 3373 and 2923 cm-1 has been observed in the GDBD plasma fig. 8 (c) rather than in the untreated and the FDBD treated samples. The NH2 groups are not increased in the treated samples. This may be due to the etching process in the plasma at high power.

2. Printing properties

2.1. Color strength

Figure 9 represents the effect of the plasma discharge current on the color strength of the printed wool fabric after treatment by FDBD Figure 9 (a), and GDBD Figure 9 (b) plasma respectively at the same treatment time t= 10 min.

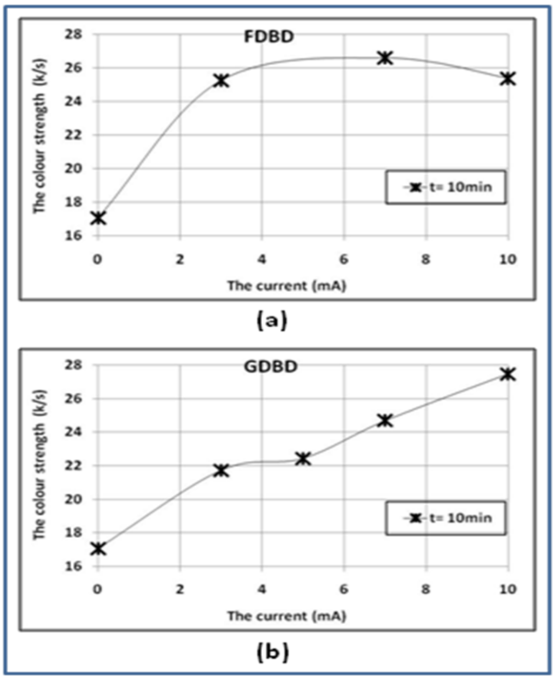

Fig. (9) The color strength as a function of the discharge current for a) FDBD and b) GDBD treated wool at treatment time t= 10 min.

An obvious increase in the color strength has been observed for the two cases of plasma treatment. However, the K/S still increases by increasing the discharge current of the GDBD plasma while it is saturates by increasing the discharge current in the FDBD plasma. This behavior is related to some reasons;

1) Increasing the discharge current in FDBD causes the increase of the number and the dimensions of the formed micro holes on the fabric surface due to increase in the number of the plasma microdischarge filaments and its dimensions. This in turns led to further absorption of the printing dyes. Therefore the concentration of the dye on the fabric surface is lower than that in its bulk. On the other hand, increasing the discharge current in the GDBD plasma causes the increase in the number of the microholes (that are resulted by the ion bombardment) in the fabric without the enhancement of its dimensions (GDBD plasma is homogenous). Therefore, the concentration of the printing dye still increases by increasing the discharge current. The color fastness results ensures this concept.

2) As it had been seen previously in the total scan of the optical emitted spectra from the FDBD and the GDBD plasma, the intensity of the peaks that emitted from the GDBD reactor is greater than that emitted from the FDBD one. So the introduction of the NH2 groups into the fiber is greater in the case of GDBD plasma which is responsible to increase the absorption of the anionic dye (acid dye) as stated by El- Khatib (2013).

Effect of the treatment time on the color strength (K/S) of the wool samples that are treated by FDBD and GDBD plasma at the same discharge current I= 10 mA is shown in figure 10.

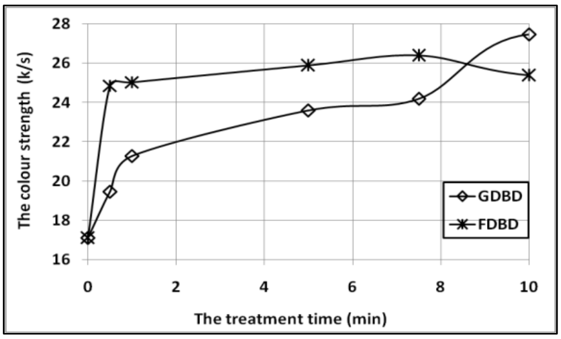

Fig. (10) The color strength as a function of the treatment time for a) FDBD and b) GDBD treated wool at discharge current I= 10 mA.

It can be noticed that the color strength (K/S) in the GDBD plasma increases gradually while it increases sharply for FDBD plasma and then it saturates. This behavior is related to the gradual increase of the microvoids number with time (for GDBD) and hence increases the concentration of the printing dye on the surface. While in the case of FDBD plasma the number and dimensions of the microvoids increase with time that causes fast diffusion of the printing dye in the fiber bulk and leaves the surface with law concentration.

2.2. Fastness Properties

Table 2 shows the Color fastness properties of the treated wool fabric after printing with Acid dye. It can be stated that an appreciable improvement in all fastness properties is encountered irrespective of type of plasma used.

Type of plasma	Condition of plasma treatment	Wash Fastness			Rubbing Fastness		Perspiration Fastness					
							Alkaline			Acidic		
		Alt.	St.		Dry	Wet	Alt.	St.		Alt.	St.	
			Cotton	Wool				Cotton	Wool		Cotton	Wool
GDBD	Untreated	3	2-3	2-3	3-4	3	3-4	2-3	2-3	3-4	3-4	3-4
	5 mA-7.5 min.	3-4	3	3-4	4	3-4	4	3-4	4	4	4-5	4-5
	5 mA-10 min.	3-4	3	3-4	3-4	3-4	4	3-4	4	4	4-5	4
	10 mA-7.5 min.	3-4	3	3	4	4	4	3-4	4	4	4	4
	10 mA-10 min.	3-4	3	3	4-5	3	4	3	3	4	4	4
FDBD	5 mA-7.5 min.	4-5	3	4-5	3-4	3	4	3	3-4	4	4	3-4
	5 mA-10 min.	4-5	3	4-5	3	3	4	3	3-4	4	4	3-4
	10 mA-7.5 min.	4-5	3	3	4-5	3	4	3	3	4	3-4	3-4
	10 mA-10 min.	4	3	3-4	4	3	4	3	3-4	4	3-4	4

Table (2) The Color fastness properties, of the un treated, GDBD and the FDBD treated wool fabric respectively, after printing with Acid dye.

The dominant results give good /very good of rating between 3-4, while in some cases they give very good /excellent fastness depending on the type of plasma used.

IV. Conclusion

A comparative study has been established between the FDBD and the GDBD plasma about their effect in the improvement of the wool fabric. It can be stated that GDBD plasma is more homogeneous than the FDBD. The optical spectra of the two types of plasma show the increasing of the peaks intensities that related to the excited nitrogen species and that are responsible in the activation of the wool surface and the formation of oxide and nitride group on the wool surface. The wettabillity has been increased by the treatment of the textile by the two types of plasma. Also the color strength and the other proprieties of the textile have been improved by plasma treatment.

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