Effect of Low Temperature Plasma Treatment on the Electroless Nickel Plating of Polyester Fabric

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ABSTRACT: The present study is performed with an objective to acquire a deeper understanding of the properties of nickel-plated polyester fabric after conducing low temperature plasma (LTP) treatment. LTP treatment with oxygen and argon gases was employed to render a hydrophilic property of woven polyester fabrics and facilitate the absorption of a palladium catalyst to provide a catalytic surface for electroless nickel plating. The properties of LTP-induced electroless nickel-plated polyester fabrics were evaluated by various standard testing methods in terms of both physical and chemical performances. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 105: 2046–2053, 2007

Key words: surface; low temperature plasma; electroless nickel plating; polyester; fiber

INTRODUCTION

Low temperature plasma (LTP) treatment is commonly employed as an effective means of surface morphology modification of textiles fibers to enhance certain properties.[1] Exposure to suitable plasma is able to alter the uppermost atomic layers of the material surface while leaving the desirable bulk properties unaffected.[2] The LTP reaction is greatly dependent on the machine power supply, gas type, gas pressure, and treatment time.

Electroless plating is a novel technique applied to textile materials to efficiently produce fabrics with a brilliant appearance. Solution containing reducing agent and metal ions provides chemical reaction and facilitates metal deposition to generate metal coatings on fabrics.[3,4] The effect of metal coating in electroless plating is dependent on the chemical concentration, pH value of the solution, temperature, duration, as well as the surface area of substrate to be plated. Recently, there are increasing interests in the application of electroless plating to metallize different metal granules on the fabric surface to achieve brilliant design effects in textile market.[3–5]

Apart from design creativity, the electroless nickel plating (ENP) stands out several benefits like ultraviolet (UV) protection, water repellency, conductivity, and antistatic.[6] However, the results of electroless plating are various due to the unstable metal adhesion reaction during metal deposition stage. As a result, LTP treatment is introduced to alter the surface morphology of woven polyester fabrics before ENP, to enhance its hydrophilic and absorption properties, to achieve the improvement of plating effect.[7]

This article investigates the properties of polyester fabrics after ENP as well as the effect of LTP treatment using two different gases namely oxygen and argon on the improvement of performance of nickel-plated polyester fabrics.

EXPERIMENTAL

Sample preparation

Hundred percentage polyester plain weave fabric with white color was used and its specifications were shown in Table I. In view of the fact that oil and impurities would scatter on the fabric surface randomly during manufacturing, the fabric was washed in 2% nonionic detergent at pH 7 and 40°C for 20 min, and then rinsed with deionized water for about 5 min. The cleaned fabric samples were conditioned under standard atmospheric pressure at 65% ± 2% relative humidity and 21°C ± 1°C for at least 24 h prior to all experiments.

LTP treatment

A glow discharge generator (Showa, Japan) was used for the LTP treatment of the polyester fabrics. The glow discharge system was a radio-frequency etching system operating at 13.56 Hz. Two kinds of nonpolymerizing gases namely oxygen and argon, with a flow of 20 cc/min, were used. The discharge

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TABLE I
Fabric Specification

Fabric weight (g/m^2)	77
Yarn count (Tex)	
Warp	8.4
Weft	8.7
Fabric density	
Ends/cm	49
Picks/cm	38

power and system pressure were set at 50 W and 40 Pa, respectively. The fabric samples were subsequently exposed to oxygen or argon LTP treatment for 5 min. After LTP treatment, the LTP-treated fabric samples were conditioned under standard atmospheric pressure at 65% ± 2% relative humidity and 21°C ± 1°C for at least 24 h prior to all experiments and measurements.

Electroless nickel plating

The ENP process was basically divided into five main stages including (i) precleaning, (ii) sensitization, (iii) activation, (iv) electroless nickel deposition, and (v) posttreatment. In the ENP process, unless otherwise stated, all chemicals used were in A.R. grade. To facilitate the metal particles plated on the fabric surface, the pretreatment processes consisting of precleaning, sensitization, and activation were conducted. In the pretreatment stage, all fabric samples were precleaned in a 2% nonionic detergent at pH 7 and 40°C for 20 min. Deionized water was then used for rinsing the precleaned samples. In the case of sensitizing fabric surfaces, the cleaned fabric samples were subjected to the surface sensitizer, which was a mixture of 5 g/L stannous chloride and 5 mL/L hydrochloric acid, with slow agitation for 10 min at 25°C and pH 1. The sensitized fabrics were rinsed with deionized water subsequently. Fabric samples were finally immersed in the activator, which was composed of 0.3 g/L palladium (II) chloride, 0.5 mL/L hydrochloric acid (conc. 37%), and 20 g/L boric acid, at pH 2 and 25°C for 5 min, to achieve surface activation. The activated fabrics were rinsed with deionized water afterwards.

During the deposition stage, the nickel plating solution was employed in the ENP tank, which was composed of 15 g/L nickel (II) sulfate 7-hydrate, 8 g/L trisodium salt dehydrate, 18 g/L ammonium chloride, a few drops of sodium hydroxide (conc. 10%), and 15 g/L sodium hypophosphite monohydrate. The activated fabrics were immersed in the nickel plating solution at pH 9 and 40°C for 20 min with constant stirring for metallizing reaction.

In the posttreatment stage, all the nickel-plated fabrics were rinsed with deionized water at 40°C for 20 min right after the metallizing reaction of ENP. The cleaned nickel-plated fabrics were then cured by steaming machine (Mathis Labdryer, Werner Mathis AG, Switzerland) directly at 150°C for 1 min.

All ENP-treated fabric samples were conditioned under standard atmospheric pressure at 65% ± 2% relative humidity and 21°C ± 1°C for at least 24 h before further evaluation.

Measurement of weight change

The weight of all samples with the size of 20-cm square was measured by the Sartorius BP211D Electronic Balance (Sartorius, Germany). The percentage change of fabric weight was calculated with eq. (1) as follows:

$$\text{Weight change (\%)} = \frac{W - W_o}{W_o} \times 100 \qquad (1)$$

where W is weight of the substrate after treatment (g) and W_o is initial weight of the substrate (g).

Fabric thickness

The fabric thickness of test specimens, before and after the ENP process, was measured by the Fabric Thickness Tester (Hans Baer AG Ch-Zurich Telex 57767) with a pressure of 10 g/cm^2. After measurement, the result was calculated by the eq. (2) to show the change of fabric thickness.

$$\text{Change in thickness (\%)} = \frac{T - T_o}{T_o} \times 100 \qquad (2)$$

where T is the fabric thickness of the substrate after treatment (mm) and T_o is the initial fabric thickness of the substrate (mm).

Scanning electron microscopy

The surface morphology of the test specimens was investigated by the scanning electron microscope—Leica Stereoscan 440 (Leica Cambridge, England), with 20 KV accelerating voltage at a magnification of 30,000.

TABLE II
Measurement of Fabric Weight

Sample	Without LTP treatment	With oxygen LTP treatment	With argon LTP treatment
Original (g)	3.08	3.08	3.08
Nickel-plated (g)	3.38	3.33	3.35
Weight change (%)	↑9.87	↑8.02	↑8.86

TABLE III
Measurement of Fabric Thickness

Sample	Without LTP treatment	With oxygen LTP treatment	With argon LTP treatment
Original (mm)	0.270	0.270	0.270
Nickel-plated (mm)	0.272	0.280	0.275
Weight change (%)	↑0.74	↑3.70	↑1.85

UV radiation protection

The UV blocking effects of the fabric specimens were measured in accordance with the Australian/New Zealand Standard AS/NZS 4339 (1996) by the Cary 300 Conc UV–Visible Spectrophotometer (Varian, Palo Alto, CA), with the scope of wavelength ranging from 280 to 400 nm. The value of UV protection factor (UPF) was recorded and the result of sun protective clothing was classified according to the rated UPF.

Tensile strength

The tensile properties of all fabric specimens were evaluated in accordance with ASTM D 5034-95 with a tensile testing machine (Instron 4411; Instron, Norwood, MA).

Tearing strength

The tearing strength of fabric specimens was evaluated using the Elmendorf Tearing Tester (Thwing-Albert Instrument, Philadelphia, PA) according to ASTM D 1242-96.

Color fastness assessment

Three standard testing methods were used for assessing the color fastness of the ENP-treated fabrics

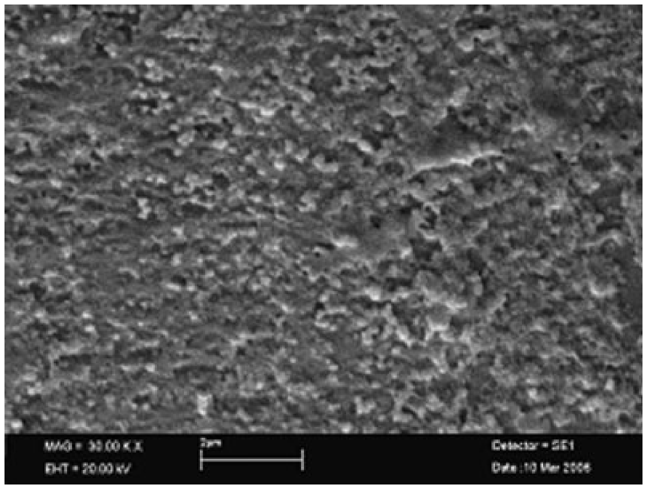

Figure 2 Scanning electron micrograph of oxygen LTP-treated polyester fiber (30,000×).

under different application conditions: (i) AATCC 8-2004 (color fastness to crocking), (ii) AATCC 16-2004 (color fastness to light), and (iii) AATCC 61-2003 (color fastness to laundering).

Contact angle

The water repellent property of the fabric specimens was measured by the Contact Angle Meter with the model of CAM-Micro (Tantec, Denmark). Three types of test specimens, i.e., without LTP treatment, oxygen LTP treatment, and argon LTP treatment, were assessed before and after washing according to the washing procedure of AATCC 61-2003.

Wrinkle recovery

The wrinkle-resistant property of fabric specimens was evaluated before and after the ENP. Wrinkle

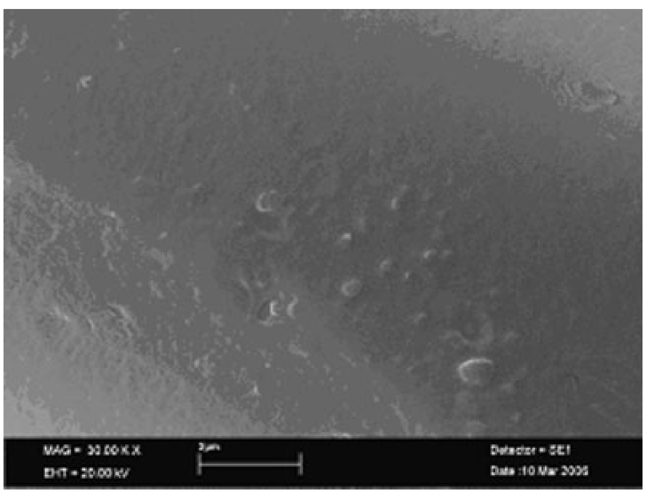

Figure 1 Scanning electron micrograph of original (control) polyester fiber (30,000×).

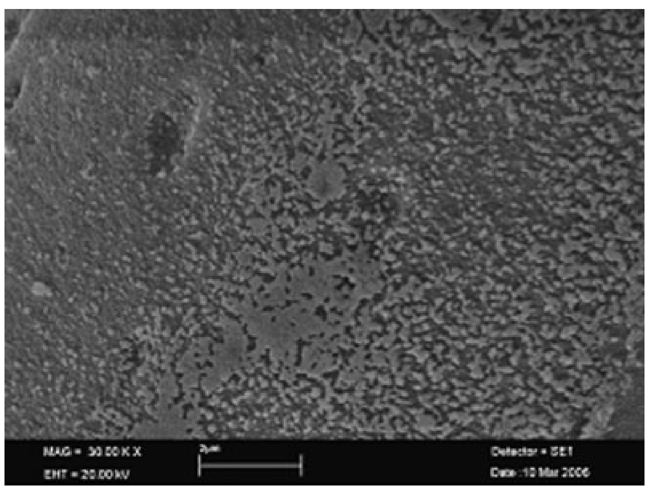

Figure 3 Scanning electron micrograph of argon LTP-treated polyester fiber (30,000×).

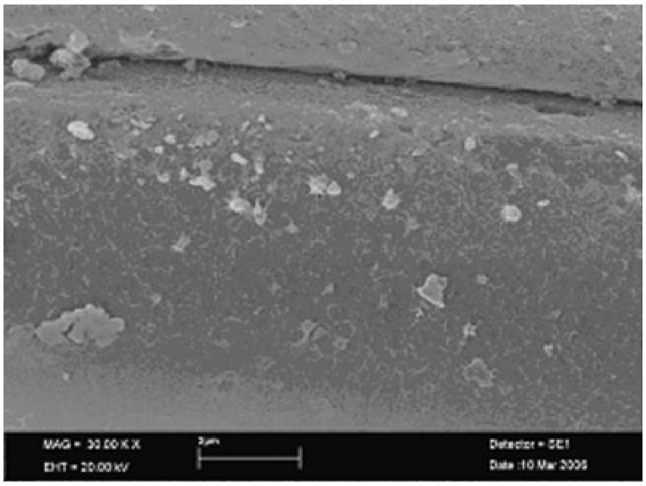

Figure 4 Scanning electron micrograph of nickel-plated fiber without LTP treatment (30,000×).

recovery angles were measured by the wrinkle recovery tester and its accessories (Daiei Kagaku Seiki, Japan) according to the AATCC 66-1998.

RESULTS AND DISCUSSION

Measurement of weight change

The calculated changes in fabric weight of the nickel-plated polyester fabrics after three pretreatment conditions, i.e., without LTP treatment, oxygen LTP treatment, and argon LTP treatment, are shown in Table II.

The growth in fabric weight of the nickel-plated polyester fabrics with the application of both oxygen and argon LTP treatment is less than those without LTP treatment. One reason of the weight loss in fabrics after LTP treatment is possibly a consequence of competition effect. LTP treatment reduces the fabric weight by etching the fabric surface. However, the increase in fabric weight by the deposition of nickel particles during ENP cannot compensate for the weight loss due to LTP treatment. As a result, the growth in fabric weight is only moderate when compared with the fabrics without LTP treatment.

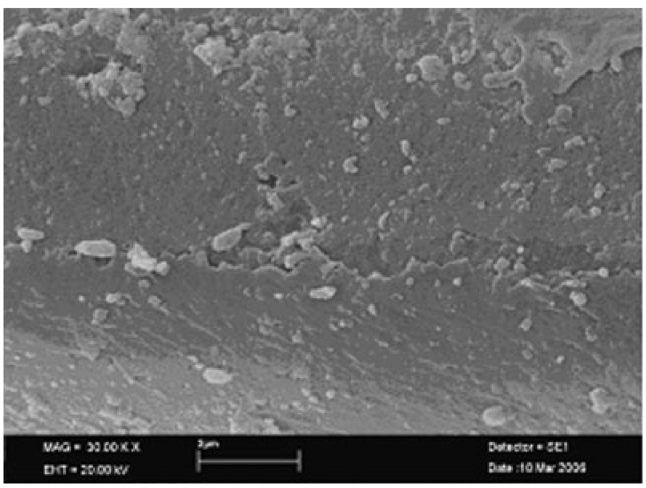

Figure 5 Scanning electron micrograph of nickel-plated fiber with oxygen LTP treatment (30,000×).

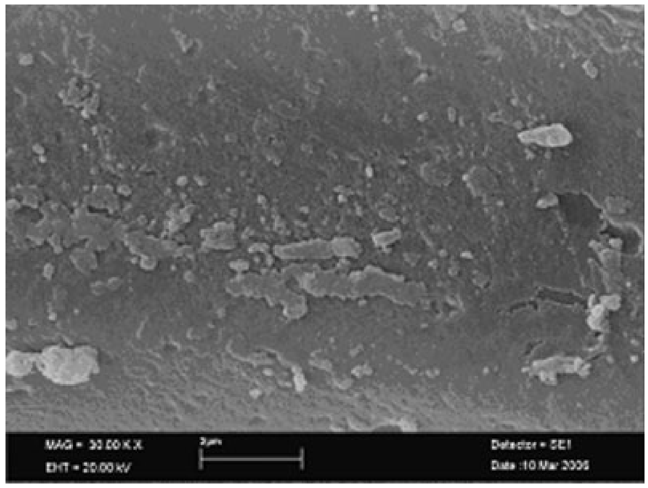

Figure 6 Scanning electron micrograph of nickel-plated fiber with argon LTP treatment (30,000×).

Since the adhesion performance is enhanced by LTP treatment,[8] thus nickel particles are easier and faster to coat on the fabric surface. However, this coated layer restricts the other nickel particles in plating solution to approach the fabric, the growth of fabric weight, therefore, is reduced.[7]

Thickness

The changes in fabric thickness of nickel-plated polyester fabrics after the oxygen and argon LTP treatments are summarized in Table III.

There is an increase in thickness of fabric surface for the electroless nickel-plated polyester fabrics, regardless of whether there is LTP treatment or not as shown in Table III. After LTP treatment, the increase in fabric thickness of electroless nickel-plated polyester fabrics is more obvious than those without LTP treatment. In view of the increase in fabric thickness, oxygen LTP treatment is more effective than argon LTP treatment in terms of the

TABLE IV
Ultraviolet Protection Factor of Nickel-Plated Polyester Fabrics

	Nickel-plated polyester fabrics	
Treatments	Mean UPF	UPF rating
Without LTP treatment	103.66	50+
Oxygen LTP treatment	168.42	50+
Argon LTP treatment	161.47	50+

TABLE V
Tensile Strength of the Fabric

Sample	Control	Nickel-plated without LTP treatment	Nickel-plated with oxygen LTP treatment	Nickel-plated with argon LTP treatment
Tensile strength in warp direction (N)	322.10	339.20	352.60	352.75
Tensile strength in weft direction (N)	219.05	250.90	259.10	253.35
Average (N)	270.58	295.05	305.85	303.05

improved performance of nickel deposition on polyester fabrics. When compared, oxygen LTP treatment has almost 4% growth, whereas argon LTP treatment only increases about 2%.

The thickness of fabric is normally determined by the amount of nickel particles coated on the fabric surface. However, it is also affected by the removal of particles during the rinsing steps in plating process. The more the particles being removed, the thinner the fabric thickness will be. On the contrary, with LTP, the increase in fabric thickness is noticeable because the amount of particles being removed is reduced. This can justify that LTP treatment is able to improve the adhesion ability of nickel particles.

Scanning electron microscopy

Scanning electron microscopy (SEM) image was observed to comprehend the alteration of surface morphology of LTP-treated fabrics and nickel-treated fabrics. The fiber surfaces after LTP treatment and chemical nickel plating process are shown in Figures 1–3 with a magnification of 30,000.

Figure 1 demonstrates the SEM image of untreated polyester fiber, while Figures 2 and 3 display the SEM images of LTP-treated polyester fiber with oxygen and argon gases, respectively. Figure 1 clearly demonstrates that the untreated polyester fiber surface is smooth and free from roughness, indicating that no damage occurs on the fibers surface. However, in Figures 2 and 3, the SEM micrographs of fabric sample treated with oxygen LTP treatment and argon LTP treatment, respectively, illustrate a change in the fiber surface morphology.

When compared with the argon LTP treatment, the oxygen LTP plasma treatment has a more severe damage on the fiber surface. This is probably due to the comparatively slow rate of physical etching introduced by the argon plasma gas. In summary, LTP treatment with oxygen gas is more efficient to achieve the surface etching effect. It also signifies that a stronger porous surface effect is created on the oxygen LTP-treated polyester fibers.

Figures 4–6 illustrate the SEM images of electroless nickel-plated polyester fibers under three different conditions including (1) no LTP treatment, (2) with oxygen LTP treatment, and (3) with argon LTP treatment.

The SEM images exhibit that all nickel-plated polyester fibers are fully covered by nickel particles. In particular, the fibers with LTP treatment have more nickel particles adhered along the fiber surface than those without LTP treatment. When compared with the argon LTP treatment, the amount of nickel particles adhered on the nickel-plated fiber with oxygen LTP treatment is relatively higher. This implies that the LTP treatment is able to improve the nickel deposition ability on the polyester fibers by altering its surface morphology. In addition, the results also prove that oxygen LTP treatment is comparatively more efficient than argon LTP treatment.

UV radiation protection

The UPF results were calculated using the methods described in the Australian/New Zealand Standard AS/NZS 4399 : 1996 and the effect of LTP treatment on the UV-blocking property of nickel-plated polyester fabrics is illustrated in Table IV.

Table IV shows that the mean UPF of nickel-plated polyester fabrics increases moderately after the application of LTP plasma treatment. When compared with the untreated nickel-plated polyester fabrics, the electroless nickel-plated polyester fabrics with oxygen LTP treatment have about 62.5%

TABLE VI
Tearing Strength of the Fabric

Sample	Control	Nickel-plated without LTP treatment	Nickel-plated with oxygen LTP treatment	Nickel-plated with argon LTP treatment
Tearing strength in warp direction (N)	13.49	8.47	7.84	8.62
Tearing strength in weft direction (N)	12.70	7.53	7.37	6.90

TABLE VII
Colour Fastness to Crocking of Nickel-Plated Polyester Fabrics

	Nickel-plated polyester fabrics		
Fabric directions	Without LTP treatment	With oxygen LTP treatment	With argon LTP treatment
Dry			
Warp	3	3–4	3–4
Weft	2–3	3–4	3–4
Wet			
Warp	3	3–4	3–4
Weft	2–3	3	3

increases in the mean UPF. As for those with argon LTP treatment, the mean UPF increases 55.8%. The increase in UPF indicates that the overall ratings for all three different types of nickel-plated polyester fabrics, i.e. (1) without LTP treatment, (2) oxygen LTP treatment, and (3) argon LTP treatment, are graded as 50+. This indicates that the nickel-plated polyester fabrics can provide an excellent protection of UV radiation. Therefore, the effect of LTP treatment on the UV-blocking performance is not significant.

Tensile strength

The effect of LTP treatment on the tensile strength of nickel-plated polyester fabrics is demonstrated in Table V.

Table V illustrates that the tensile strength of polyester fabrics increase in both warp and weft directions after the ENP. For warp direction, the tensile strength of nickel-plated polyester fabrics with oxygen LTP treatment or argon LTP treatment is slightly stronger than that without LTP treatment. However, for weft direction, the increase in tensile strength for all the nickel-plated polyester fabrics (1) without LTP treatment, (2) with oxygen LTP treatment, and (3) with argon LTP treatment is similar.

From Table V, it shows that the maximum breaking load is further increased after the application of LTP treatment. Both oxygen and argon LTP treatments can contribute greatly to the increase in tensile strength.

TABLE VIII
Colour Fastness to Light of Nickel-Plated Polyester Fabrics

Treatments	Nickel-plated polyester fabrics (colour change)
Without LTP treatment	Above 4
Oxygen LTP treatment	Above 4
Argon LTP treatment	Above 4

The overall results indicate that the average tensile strength shows an upward tendency. After the LTP treatment with oxygen and argon gases, electroless nickel-plated polyester fabrics are proved to have great improvement in tensile property.

Tearing strength

The effect of LTP treatment on the tearing strength of nickel-plated polyester fabric is shown in Table VI. Tearing force of polyester fabrics has deteriorated sharply in both warp and weft directions after being subjected to ENP. This is probably due to the fact that the extremely high and low pH value conditions during plating will damage fiber interbondings, resulting in weakening of the fibers. Results justify that both oxygen and argon plasma treatment are insignificant to improve the tearing strength.

Color fastness to crocking

The effect of LTP treatment on the color fastness to crocking of nickel-plated polyester fabrics was assessed by two observers in accordance with the AATCC Specification and the results are reported in grade scale as shown in Table VII.

The results in Table VII show that there is a slight improvement in color staining after LTP treatment. Under dry and wet crocking condition in warp direction, the color fastness result of all the nickel-plated polyester fabrics are rated as Grades 3–4.

As for the dry crocking fastness in weft direction, the nickel-plated polyester fabric without LTP treatment is rated as Grades 2–3; while the fabrics subjected to oxygen and argon LTP treatments are rated Grade 3–4. Conversely, there is a slight improvement in wet crocking fastness of all the nickel-plated polyester fabrics in weft direction and they are rated as Grade 3.

On the whole, the crocking fastness of nickel-plated fabrics is comparatively above the commercial requirement. This signifies that only some nickel granules are lost during rubbing, which is attributed to the favorable adhesion ability of nickel attached on polyester fabrics.[9,10]

TABLE IX
Colour Change of Nickel-Plated Polyester Fabrics

Treatments	Nickel-plated polyester fabrics (colour change)
Without LTP treatment	4–5
Oxygen LTP treatment	4–5
Argon LTP treatment	4–5

TABLE X
Colour Staining of Nickel-Plated Polyester Fabrics

Treatments	Nickel-plated polyester fabrics (colour staining)					
	Wool	Acrylic	Polyester	Nylon	Cotton	Acetate
Without LTP treatment	4–5	4–5	4–5	4–5	4–5	4–5
Oxygen LTP treatment	4–5	4–5	4–5	4–5	4–5	4–5
Argon LTP treatment	4–5	4–5	4–5	4–5	4–5	4–5

Color fastness to light

The effect of LTP treatment on the color change of nickel-plated polyester fabric against light is reported in Table VIII.

The results of the light fastness of all nickel-plated polyester fabrics are above Grade 4, which can pass the commercial requirement. This indicates that LTP treatment with both oxygen and argon gases cannot affect the property of color fading under sunlight exposure. In addition, the nickel-plated polyester fabrics are able to withstand the artificial light under the prescribed condition of simulated light climate. Hence, the nickel-plated polyester fabrics are absolutely stable under normal lighting condition.

Color fastness to laundering

The color change of test specimens and the assessment of staining on the multifiber fabrics were evaluated using Gray Scale for Assessing Color Change and Gray Scales for Accessing Staining, respectively. Both evaluations were conducted by two observers under illuminant D65. The average grade number of each specimen is reported in Tables IX and X.

Tables IX and X indicate that all the nickel-plated polyester fabrics have good washing fastness property in terms of both color change and color staining. In view of the color change performance, the visual assessment shows that all the nickel-plated polyester fabrics have very good color fastness, i.e., Grades 4–5. This obviously confirms that almost no color fading occurs during laundering, and all the nickel-plated polyester fabrics remain unchanged after five cycles of washing, regardless of the application of LTP treatment of oxygen and argon gases. When considering the staining performance, all the nickel-plated polyester fabrics are rated as Grades 4–5. The overall results indicated that there is no staining caused by washing, as a result of LTP treatment with oxygen or argon gas. Based on the results obtained from color change and color staining, it is confirmed that no nickel particles are lost during washing.

Contact angle

The water-repellent properties, i.e., before and after washing, of the nickel-plated polyester fabrics with or without LTP treatment are expressed in terms of contact angle and absorption time as shown in Table XI.

The untreated polyester fabrics normally have poor water-repellent property. However, the performance is enhanced after ENP with or without LTP treatment. Table XI shows that the nickel-plated polyester fabrics without LTP have the highest contact angle before washing, followed by the argon LTP treatment and LTP plasma treatment, respectively. However, the contact angle of all the nickel-plated polyester fabrics drops to the same level after washing. When compared, the untreated polyester fabrics have a quick absorption time, which is less than 1 s. However, all the nickel-plated polyester fabrics, including those without LTP treatment, with oxygen LTP treatment, and with argon LTP treatment, can provide a sufficient and effective water-repellent property, which have more than 30 s absorption time. The overall results indicated that there is no improvement in contact angle.

Wrinkle recovery

Wrinkle recovery test was applied to evaluate the wrinkle retention property after the ENP with LTP treatment. The results of wrinkle recovery of nickel-plated polyester fabrics with and without LTP treatment are shown in Table XII.

In both warp and weft directions, the wrinkle recovery angle of electroless nickel-plated polyester

TABLE XI
Absorption Time

Treatment	Control	Nickel-plated without LTP treatment	Nickel-plated with oxygen LTP treatment	Nickel-plated with argon LTP treatment
Before washing	1 s	30+ s	30+ s	30+ s
After washing	1 s	30+ s	30+ s	30+ s

TABLE XII
Wrinkle Recovery Angle of the Fabric

Sample	Control	Without LTP treatment	With oxygen LTP treatment	With argon LTP treatment
Recovery angle in warp direction	152.67°	150.00°	155.33°	153.33°
Recovery angle in weft direction	146.33°	145.33°	149.00°	147.33°
Average	149.50°	147.67°	152.17°	150.33°

fabrics is slightly improved except those fabrics without LTP treatment. The result evidences that there is a slight improvement of wrinkle recovery of electroless nickel-plated polyester fabrics after the application of LTP treatment. When compared, the electroless nickel-plated polyester fabrics with oxygen LTP treatment provide a better wrinkle recovery property than those fabrics with argon LTP treatment, whereas the electroless nickel-plated polyester fabrics without LTP treatment encounter a decline in wrinkle recovery property.

REACTION MECHANISM

LTP treatment is a selective surface treatment process, the nature of the plasma gas used plays an important role in modifying the polymer surface properties.[11,12] With the use of oxygen plasma gas on polyester, polar groups such as —OH, —OOH, and —COOH may be introduced on the polyester fiber surface.[11,12] These polar groups may enhance the hydrophilicity of the polyester fiber. On the other hand, with the use of argon gas for the LTP treatment on polyester, a two-step process may occur, i.e., exposure to argon LTP and contact with oxygen, which leads to a surface that is hydrophilic in nature due to the formation of polar functional groups.[13] At the same time, the roughness at the surface also appears. The magnitude of this change at the surface is time dependent. As the time of exposure increases, the surface becomes richer in oxygen functionality but also rougher.[13] Therefore, in both cases of LTP treatment with oxygen and argon, the physicochemical on the polyester fiber surface may improve the fiber hydrophilicity and hence enhance the subsequent wet processing such as ENP process consequently.

CONCLUSIONS

In this article, the effect of LTP treatments using oxygen and argon plasma gases on the nickel-plated polyester fabrics has been examined. A series of standard tests are conducted to evaluate and compare the performance of LTP plasma treatments including measurement of weight change, fabric thickness, SEM, UV radiation screen, tensile strength, tearing strength, color fastness to crocking, color fastness to light, color fastness to laundering, contact angle, and wrinkle recovery.

When compared, the ENP with LTP treatment is significant to improve the performance of nickel-plated polyester fabrics as reflected by the SEM, tensile strength, UV protection, fabric weight, as well as wrinkle recovery. On the contrary, it also enhances the fabric thickness and color fastness to crocking. In addition, there is no influence on the performance of color fastness to light and colorfastness to laundering. Moreover, the application of LTP treatment reduces the performance of tearing strength and contact angle.

When the two LTP gases are compared, oxygen LTP treatment has tremendous effect on the nickel-plated polyester fabrics. SEM indicates that oxygen LTP treatment is more effective than argon LTP treatment in changing the fabric surface morphology, so as to enhance the nickel-plated polyester fabrics properties. On the whole, the LTP treatment can successfully improve the ENP performance. In addition, oxygen LTP treatment is comparatively more efficient than argon LTP treatment.

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