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Effect of Treatment with Laser/Titanium Dioxide Nanoparticles on Printability of Cellulose Acetate Fabric with Disperse and Natural Dyes

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Abstract

This work studied the effect of treatments of cellulose acetate (CA) fabric with nano titanium dioxide Nano-particles (TiO2 NPs) in alcoholic media and combined excimer laser/ TiO2 NPs on the fabric printability with both disperse and turmeric natural dye. The cellulose acetate fabric was treated with various concentrations of TiO2 NPs (0.3-1.0 % o.w.f) using a padding technique, squeezing to 100 % pick up, and then cured thermally at 110 0 C for 5 min or via subjecting to microwave irradiation for 60s. The treated cellulose acetate was printed with both C. I. Disperse Red 167 and turmeric natural dyes. The printability of the treated CA fabric was evaluated by measuring the color strength (K/S) as well as the fastness properties. The results showed that treatment with TiO2 NPs in alcoholic media as well as laser/ TiO2 NPs improved the printability of CA fabric with both disperse and turmeric dyes. The treatment with TiO2 NPs in an ethanol solution of concentration 50% (v/v) after laser treatment resulted in the highest color strength and color fastness. The use of turmeric dye, padding methodology for treatment as well as laser irradiation gives high potential for enhancing the printability of cellulose acetate fabric with natural dyes and provides a sustainable and friendly technique as an alternative to disperse dyes.

Keywords: Cellulose Acetate, Natural Dye, Laser, Nano Particles, Titanium Dioxide, Alcohols.

Introduction

Nanoparticle treatments have recently been applied to producing smart textiles and improving their properties. [1, 2] Nanoparticle treatments improve the antibacterial activity, water or oil repellence, antistatic properties, self-cleaning, and flame retardancy as well as improving printability and dyeability. [3] Cellulose acetate fibers are normally printed with dispersed dyestuff with good quality. The development of cellulose acetate printability depends on widely the rates of dye absorption and leveling properties. [4] The printability of textiles depends on their physical and chemical structure. Also, the degree of crystallinity and amorphous regions of the polymer affect their ability to uptake dye molecules. The printability of cellulose acetate could be improved by treatment with some alcohols. Adsorbing NPs onto the fiber can enhance its printability as well as fastness properties. [5-16] Cellulose acetate (CA) fabric is treated with TiO_2 NPs in water/ethylene glycol (1:1) by the pad-dry-cure method to enhance its properties such as self-cleaning. Other properties such as tensile strength, roughness, and wettability were enhanced [17] Coating textiles with titanium dioxide nanoparticles can provide new properties such as printability, UV protection, and medical applications. [18-26]

Cellulose Acetate (CA) fabrics were treated with excimer laser irradiation. The changes in surface morphology were investigated by scanning Electron Microscopy (SEM). The effect of laser treatment on the coloration properties with the dispersed dye of cellulose acetate fabrics was characterized. The

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wettability, surface roughness, and fastness properties were found to be enhanced. It was also found that laser treatment of cellulose acetate was more effective in enhancing its ability to uptake and disperse dye than dyeing via ultrasonic technique under the same conditions. [27-29] Excimer laser treatment results in etching of CA surfaces. The induced changes in the physical and chemical properties of textile fibers as a result of surface modification had important impacts on textile processing. The coloration properties, wettability, and surface luster were found to be improved after laser treatment. [30, 31]

The current work was undertaken to improve the printability of cellulose acetate fabrics with both dispersed and natural dyes through treatment with TiO_2 NPs. Thus nanoparticles of TiO_2 were dispersed in a mixture of water/alcohols. Mono-, di-, and tri-hydric alcohols are used as treatment media. The treatment was carried out via the pad-dry-cure method. The treatment was performed under different conditions including concentration of TiO_2 NPs, concentration of alcoholic media, and curing method (thermally or by microwave irradiation). Also, pretreatment of CA fabrics with an excimer laser under different exposure time intervals before NP treatment is tried. The improvements in printability of CA fabric with dispersing and turmeric dyes are evaluated by measuring the color strength and fastness properties.

Experimental

Materials

White satin cellulose acetate fabric of 38.5% acetyl content was used. The fabric was washed in an aqueous solution containing 3g/1 nonionic detergent (Hostapal CV, Clariant), at 60°C for 20 min, then thoroughly rinsed with water and dried at ambient conditions.

Ethanol, ethylene glycol, glycerol, and titanium dioxide (TiO_2) NPs of pure grade (supplied from Merck, Germany) were used.

Thickeners: Natural gum ST 80 for disperse dye and berlin metal CM for natural dye

Commercial dye such as CI Disperse Red 167 from Bayer Co of known chemical structure was used in this study. Turmeric tincture was bought from the local market.

Treatments

Alcohol/water solutions of different concentrations (10-50 % v/v) containing TiO_2 NPs were prepared. The used alcohols are ethanol, ethylene glycol, and glycerol. The concentrations of NPs are 0.3, 0.5, and 1 g/100g fiber. Then the solution is subjected to sonication for 60s to get homogeneity. The CA samples were padded in the aforementioned solutions for 30 min and then squeezed to pick up 100%. Other samples were exposed to laser (Excimer Laser, power: 500 MW, λ1064nm, pulse) for 60-120 s and then treated with TiO_2 NPs in alcoholic media under the same conditions mentioned above. The treated samples were cured either in an oven (DPTA79/08, Carbolite) for 5 min at 115° C or in a microwave (model KOR-1316 Olympic Electric, Korea) for 60 s at 100% power.

Printing Procedure

Textile printing includes several techniques. Screen printing is a simple conventional method. The screen printing process is shown in (Fig 1). Generally, the screen is placed upon a fabric, where the printing paste is pressed through holes of the screen to print the fabric. Lastly, the printed fabric is then cured at a high temperature of 110°C in a steamer for 15 min.

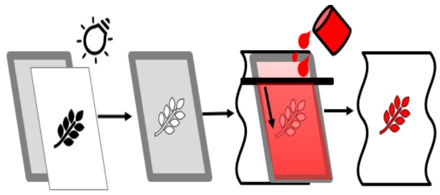

Fig. 1. Overall Process of Screen Printing

The printing paste recipe of dispersed dye:

Thickener	50 g
Acid donor	0.5 g
Carrier	2.0 g
Oxidation agent	0.5 g
Disperse dye	5.0 g
Water	X g
	100 g

The printing paste recipe of natural dye:

Synthetic thickener	2.0 g
Binder	5.0-20.0 g
Urea	4.0 g
Dyes	3.0 g
Water	X g
	100 g

The steamed fabrics were washed in water containing 2g/l nonionic detergent at 40°C for 20 min. then rinsed in cold running water and air dried at ambient conditions.

Color Strength

The color strength (K/S) values were measured using a spectrophotometer (Ultra Scan PRO Hunter lab, USA). The color strength is expressed as a K/S value where:

K is the absorption coefficient depending on the concentration of the colorant,

S is the scattering coefficient caused by the colored substrate

K/S was measured at a wavelength of 400-700 nm within the visible spectrum. The K/S values at the maximum wavelength (λ_{max}) were summed according to Kubelka -Munk equation: [32-34]

$$K/S = \frac{(1-R)^2}{2R} - \frac{(1-R_o)^2}{2R_o}$$

Where R is decimal fraction of the reflectance of the printed samples,

R_o is the decimal fraction of the reflectance of the unprinted samples.

The higher the K/S value, the greater the dye uptake was, resulting in a better color strength.

Color Fastness

The color fastness of the printed fabrics was assessed by the AATCC Test Method 16-2001, AATCC Test Method 612001, [35] and AATCC Test Method 82001 [36] for light, washing, and rubbing fastness respectively.

Results and Discussions

The coloration of textiles depends on their physical and chemical structure. The acetyl and hydroxyl groups in CA fibers form H bonds with water molecules resulting in swelling of the fiber and an increase in the absorption of dyestuff. Also, the proportion of crystalline and amorphous regions of the polymer affects the coloration properties. Adding NPs to the fiber would improve its coloration properties. [8, 37-42]

Printing With Disperse Dye

Effect of Alcohol Concentration

The relation between the concentration of alcohols (v/v %) as media of treatment and the color strength (K/S) of printed CA samples is shown in Figs (2, 3). Figure (2) represents this relation for cellulose acetate cured thermally after treatment with Nanoparticles in an oven, while Fig (3) represents the same relation for samples cured via exposure to microwave irradiation. It is shown that as the concentration of alcohols increased from 10 to 50 (v/v %), the color strength increased. That is due to cellulose acetate fabric becoming able to absorb water more than untreated one after treatment with TiO_2 NPs in ethanol, ethylene glycol, and glycerol media. Using ethanol solution as a treatment medium was found to be the most effective one in enhancing the color strength of treated CA fiber either cured thermally or by microwave irradiation (Figs 2, 3).

The samples fixed in the oven after treatment with TiO2 NPs in alcoholic media give approximately the same results of color strength of printed CA with dispersed dye. The color strength is nearly more than doubled for treated CA compared to untreated one. The noticed increase in color strength may be attributed to the physical changes on the surface of CA and increasing fiber diameter due to the swelling effect of alcoholic media. Consequently the uptake of dye by the fiber increases.

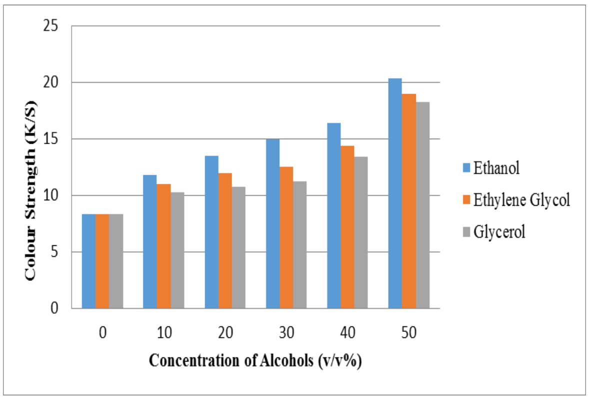

Fig. 2. Effect of concentration of alcohols on color strength of treated CA with TiO_2 fiber, thermally cured, and printed with dispersed dye

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs - Curing : 110°C, 5 min.

Printing: C. I Disperse Red 167, steaming, 110°, 15 min

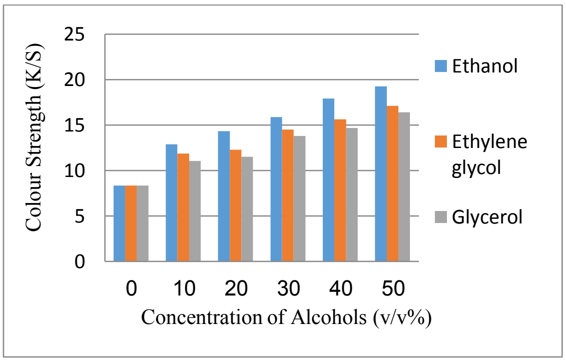

Fig. 3. Effect of concentration of alcohols on color strength of treated CA with TiO_2 fiber, cured via microwave irradiation, and printed with dispersed dye

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs - Curing: 60 s

Printing: C. I Disperse Red 167, steaming at 110° for 15 min

Effect of TiO_2 NPs Concentration

Figure (4) illustrates the dependence of the color strength of printed CA with dispersed dye and the concentration of TiO_2 NPs as a treatment agent in the ethanolic medium. It is seen that when the concentration of TiO_2 NPs increased from o.3 to 0.5% (o.w.f), the color strength of CA increased. Further increase in the concentration (up to 1%) resulted in a decrease of K/S but it is still better than the untreated CA one. That may be due to when the concentration of TiO_2 NPs was large, an agglomeration of particles formed on the surface and it disserves absorption of the dye into the fiber.

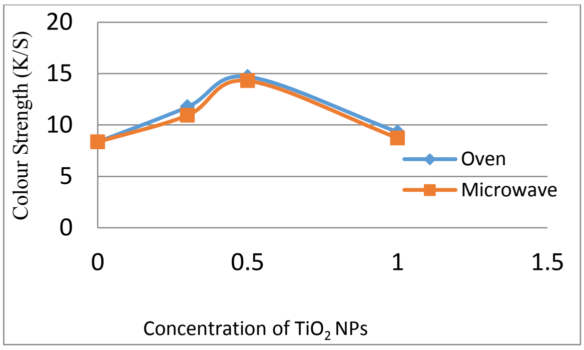

Fig. 4. Effect of TiO_2 NPs concentration in ethanolic medium on color strength (K/S) of printed CA with disperse dye

Treatment: padding, pick up100%, 25°C, (50:50 v/v) ethanol/ water
Curing: oven; 110°C, 5 min, microwave; 60s
Printing: C. I Disperse Red 167, steaming at 110° for 15 min

Effect of Time of Pretreatment with Laser

Table (1) represents the color strength (K/S) values for untreated and treated cellulose acetate fibers printed with C. I Disperse Red 167. The samples were subjected to pulse laser irradiation (500 MW, λ1064 nm) for different time intervals (60, 90,120 s). Then the laser-treated fabric was further treated with TiO2 NPs 0.5 % (o.w.f) in an ethanol/water bath of concentration 50:50 (v/v). It is observed from the table that the color strength of printed fabrics increases with increasing the time of laser exposure from 60 to 90 seconds and then slightly decreases upon exposure to 120 seconds. The highest acquired K/S is 21.66 compared to 8.34 for untreated one corresponding to relative colour strength of 259.71 %. It is shown that thermal curing gives slightly better results than curing with microwave irradiation.

Printing with Turmeric Natural Dye

Effect of Used Alcohols

Some samples were treated with different alcohols such as ethanol, ethylene glycol, and glycerol solutions 50% (v/v) containing TiO2 NPs of 0.5 g % (o.w.f) using padding technique and squeezed up to pick up 100%, to measure the effect of modification on the efficiency of the treated cellulose acetate sample to adsorb turmeric natural dye. Results are illustrated in Table (2). It is shown that the treatment of cellulose acetate with TiO_2 NPs in different alcoholic media appears to increase the color intensity of the fabrics. It is also noticed that treatment in ethanolic medium is more effective than that in ethylene glycol and glycerol media in enhancing color strength (K/S). The color strength of printed treated CA improved upon curing the treated samples via microwave irradiation more than thermal curing. The highest color strength (K/S) of printed CA result attained upon treatment in ethanol/water is estimated at 6.63 which is approximately double of the untreated one. The increase in color strength may be attributed to the morphology changes in CA fabrics, increasing the surface roughness, and increasing the adsorption of NPs on the surface.

Table 1. Effect of laser exposure time on color strength (K/S) of CA treated with TiO_2 NPs in ethanolic media and printed with dispersed dye

Laser exposure time(s)	Color Strength (K/S)	
	Oven	Microwave
0	8.34	8.34
60	16.1	16.21
90	21.66	18.33
120	18.1	17.23

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs, (50:50 v/v) ethanol/ water
Curing: oven; 110°C, 5 min, microwave; 60s
Printing: C. I Disperse Red 167, steaming at 110° for 5 min
Excimer Laser: pulse, 500 mw, λ1064nm

Table 2. Effect of different alcohols on color strength (K/S) of treated CA fiber printed with turmeric natural dye

Type of Samples	Color Strength (K/S)	
	Oven	Microwav
-Untreated CA	3.37	3.37
-Treated CA with TiO_2NPs in:		
➢ Ethanol/water	4.14	6.63
➢ Ethylene Glycol/water	4.06	4.97
➢ Glycerol/water	3.46	3.83

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs, (50:50 v/v) alcohol/water
Curing : oven;110°C, 15 min, microwave; 60s
Printing: Turmeric Natural Dye, steaming at 110° for 15 min

Effect of Laser Exposure Time

Table (3) illustrates the values of the color strength of treated CA with pulse laser irradiation at 500 MW for different time intervals of 60, 90, and 120 s and printed with turmeric natural dye. It is observed that when the exposure time of the laser increases, the color strength (K/S) gradually increases. The highest K/S (5.52) was obtained when the fabric was exposed to a laser for 120 seconds.

Table 3. Effect of exposure time on the color strength of laser-treated CA printed with turmeric natural dye

Exposure Laser Time (s)	Color strength (K/S)
0	3.37
60	4.58
90	4.87
120	5.52

Excimer Laser: pulse, 500 mw, λ1064nm
Steaming: 110°C, 15 min

Effect of alcoholic media on color strength of treated CA with laser/ TiO_2 NPs

Some samples were treated with the laser for 120 seconds, and then treated with 0.5% (o.w.f) TiO2 in different alcohols (ethanol, ethylene glycol, glycerol) / water mixtures of concentration 50% (v/v). After the treatment all samples were cured via microwave irradiation for 60 seconds. The effect of this modification on the printability of cellulose acetate with turmeric natural dye is shown in Table (4). It was found that the highest value of K/S is 7.5 attained upon using ethanol solution as a treatment medium. It is also observed that the samples treated with laser/ TiO2 NPs have the highest color strength compared to those treated samples with laser (Table 3) and untreated ones. The durability of the treatment was tested after 10 washing cycles. It is proved that the K/S values were slightly decreased but the samples keep their printing quality.

It could be concluded from Tables (2-4) that the printability with turmeric natural dye is markedly improved by treatment of CA with laser/ TiO2 NPs in different alcohols (mono-, di-, and tri-hydric). The improvement in printability may be attributed to the formation of a thin, mostly uniform layer of NPs on the fabric surface. This improves the wettability and surface energy of CA fabric and consequently higher penetration and adhesion of dye molecules. So, this work can provide add-value applications in fashion and home textiles. Also, these findings may open new markets for CA fabric.

Fastness Properties

Colorfastness to washing is considered one of the most essential features of textiles and clothing in the consumer's mind. This test detects discoloration and loss of color during the washing process, as well as staining behavior. The rubbing color fastness, the color is transferred from the surface of the stained fabric to another surface by rubbing it with water and drying.

Table 4. Effect of laser/ TiO_2 NPs treatment in different alcohols on color strength K/S of CA printed with turmeric natural dye

Type of Samples	Color Strength (K/S)
-Untreated CA	3.37
- TiO_2 NPs treated CA in:	
➢ Ethanol/water	7.5
➢ Ethylene Glycol/water	6.15
➢ Glycerol/water	5.42

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs, (50:50 v/v) alcohol/water
Curing: microwave; 60s
Excimer Laser: pulse, 500 mw, λ1064nm, 120s
Printing: Turmeric Natural Dye, steaming; 110° for 15 min

Tables (5-8) represent the fastness properties of treated cellulose acetate with TiO2 NPs in alcoholic solutions either without or with excimer laser exposure. The washing (alt, st), rubbing (dry, wet), and light fastness properties were examined. Tables (5, 6) give the fastness properties of TiO2 NPs treated CA samples printed with C.I. Disperse Red 167 and fixed by steaming; at 110° for 15 min. Tables (7, and 8) give the corresponding values when cellulose acetate is printed with turmeric natural dye. All fastness properties of treated silk were found to be improved upon applying these treatments either by TiO2 NPs only or combined with laser/ NPs.

Table (5) illustrates the values of color fastness properties for treated CA fabrics in different alcoholic media and printed with C. I. Disperse Red 167. All applied media enhance all examined fastness properties. Ethylene glycol/water 50 % (v/v) as a treatment medium gives the highest results which is evaluated by 4-5 and/or 5 compared to 3 and/or 3-4 for untreated one for all tested fastness properties.

Table (6) shows the results of rubbing, washing, and light fastness properties for untreated and treated CA fiber with excimer laser for different exposure times, followed by padding in ethanol solution 50% (v/v) containing 0.5 % (o.w.f) TiO_2 NPs and then printed with C. I. Disperse Red 167. The fastness properties are improved. Increasing the laser exposure time up to 120 s resulted in higher values of all color fastness properties. The longer the exposure time to the laser irradiation, the higher the resistance to washing, rubbing, and light fastness is. These values are 5 and 4 for dry and wet rubbing fastness. They were the same values for alt and st. washing fastness. Also, the light fastness is found to be improved compared to untreated CA fabric. These results may be due to the change in surface morphology of CA fabric produced from laser treatment.

Table (7) represents the results of washing and rubbing fastness properties for both untreated and treated printed CA fiber with TiO_2 NPs in different alcoholic mediums 50 % (v/v), which are ethanol, ethylene glycol, and glycerol/ water. All samples are fixed after treatment thermally at 110°C for 5 min or by irradiation in a microwave for 60 seconds. Then the fabric is printed with turmeric natural dye and fixed via steaming. The results of alt washing fastness are 5 for treated CA compared to 4 for untreated one while staining washing fastness is 4-5 for treated CA compared to 3-4 for untreated one. Dry and wet rubbing fastness values are 4 and 3-4 for untreated samples respectively and these values increase to 5 and 4-5 for treated samples even cured thermally in an oven or by microwave irradiation.

Table (8) shows the washing and rubbing fastness of printed CA fabric with turmeric natural dye after treatment with laser alone for different exposure time intervals or laser/TiO2 NPs in different alcoholic media. It is clear from the data that all examined samples acquire washing fastness from good to very good compared to untreated ones. That may be due to the action of alcohols to partially dissolve CA fibers and form

Table 5. Fastness properties for treated CA fabrics with TiO_2 NPs in alcoholic media printed with dispersed dyestuff

Type of Samples	Rubbing Fastness		Washing Fastness		Light Fastness
	dry	wet	alt	st	
-Untreated CA	3-4	3	3-4	3	3
-Treated CA with TiO_2 NPs in:					
➢ Ethanol/water	4	3-4	4	3-4	4
➢ Ethylene glycol/water	5	4-5	5	4-5	4-5
➢ Glycerol/water	4	3-4	4	3-4	4

Treatment: padding, pick up100%, 25ºC, 0.5 % (o.w.f) TiO_2 NPs, (50% v/v) alcohol/water, Curing : 110°C, 5min.
Printing: C. I Disperse Red 167, steaming at 110° for 15 min

Table 6. Fastness properties for treated CA fabrics with laser/TiO_2 NPs in ethanolic medium printed with dispersed dyestuff concerning laser exposure time

Type of Samples	Rubbing Fastness		Washing Fastness		Light Fastness
	dry	wet	alt	st	
-Untreated CA	3-4	3	3-4	3	3
-Treated CA with laser/TiO_2 NPs for different times (s):					
➢ 60	4	3-4	4	3-4	4
➢ 90	5	4	4-5	4	4-5
➢ 120	5	4	5	4	4

Treatment: padding, pick up100%, 25ºC, 0.5 % (o.w.f) TiO_2 NPs, (50:% v/v) ethanol/water, Curing : 110°C, 5min
Excimer Laser: pulse, 500 mw, λ1064nm
Printing: C. I Disperse Red 167, steaming at 110° for 15 min

Table 7. Fastness properties for untreated and TiO_2 NPs treated CA printed with natural dye

Type of Samples	Rubbing Fastness				Washing Fastness			
	Oven		Microwave		Oven		Microwave	
	dry	wet	dry	wet	alt	st	alt	st
-Untreated CA	4	3-4	4	3-4	4	3-4	4	3-4
-Treated CA with TiO_2 NPs in:								
• **Ethanol/water**	5	4-5	5	4-5	5	4-5	5	4-5
• **Ethylene glycol/water**	5	4-5	5	4-5	5	4-5	5	4-5
• **Glycerol/water**	5	4-5	5	4-5	5	4-5	5	4-5

Treatment: padding, pick up100%, 25ºC, 0.5 % (o.w.f) TiO_2 NPs, (50% v/v) alcohol/water, Curing : 110°C, 5min., microwave; 60s
Printing: turmeric natural dye, steaming; 110° for 15 min

Table 8. Fastness properties of laser and TiO_2 NPs treated CA printed with natural dye

Type of Samples	Medium of Treatment	Exposure Time (s)	Rubbing Fastness		Washing Fastness	
			dry	wet	alt	st
-Untreated	-	0	3-4	3	3-4	3
-Treated with laser	-	60	4-5	4	5	4-5
		90	5	4-5	5	4-5
		120	5	4-5	5	4-5
-Treated with laser/ TiO_2 NPs	Ethanol/water	120	5	4-5	5	4-5
	Ethylene/water		5	4-5	5	4-5
	Glycerol/water		5	4-5	5	4-5

Treatment: padding, pick up100%, 25°C, 0.5 % (o.w.f) TiO_2 NPs, (50% v/v) alcohol/water, Curing : 110°C, 5 min
Excimer Laser: pulse, 500 mw, λ1064nm
Printing: turmeric natural dye, steaming; 110° for 15 min

H bonds with acetyl groups. Also, TiO_2 NPs work on concentrating the dye particles, so it becomes more resistant and stable to washing. It was found that the longer the exposure time to laser, the more increases in fsatness properties, the highest results at 120 s which was 5 and 4-5 for alt. and st. respectively. Results of rubbing color fastness showed that all treated textiles with laser/TiO_2 NPs and printed with turmeric natural dye are very good.

Conclusion

It can be concluded that:

- The color strength of samples treated with an excimer laser followed by treatment with TiO_2 NPs in alcoholic media was higher than that treated without subjecting to the laser.
- The color strength of samples treated with excimer laser followed by treatment with TiO_2 NPs in the ethanolic medium was higher than that treated in ethylene glycol and glycerol
- The treated samples fixed thermally printed with dispersed dye have slightly higher color strength values compared to those fixed samples via microwave irradiation after treatment.
- The enhancement in color strength (K/S) of treated cellulose acetate with TiO_2 NPs is dependent to a great extent on its concentration. Combined laser/TiO_2 NP treatments give the best color strength results of both dispersed turmeric natural dyestuffs.
- All fastness properties of treated cellulose acetate fabric printed either with dispersed or natural dyestuffs were improved upon applying these treatments either by NPs only or combined with laser/ TiO_2 NPs. Most values of washing, rubbing, and light fastness are 5 or 4-5 compared to 3-4 or 3 for untreated ones.
- The improvement in the color fastness of treated cellulose acetate fabric increases the ability of the fabric to retain its color after exposure to environmental conditions.
- The treatment of cellulose acetate fabric with laser/ NPs is considered a promising research field for developing the functionality, printability, and performance of acetate fibers.

Conflict of Interest

The authors declared no competing interests in the publication of this article

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تأثير المعالجة بواسطة الليزر / جزيئات ثاني أكسيد التيتانيوم النانوية على قابلية طباعة نسيج اسيتات السيليلوز بالصبغات الطبيعية والمشتتة

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المستخلص:

درس هذا العمل تأثير معالجات نسيج أسيتات السيليلوز مع جزيئات ثاني أكسيد التيتانيوم النانوية (*TiO2 NPs*) في الوسائط الكحولية وأيضا باستخدام المعالجة المسبقة بواسطة إكسيمر ليزر على قابلية طباعة النسيج بكل من الصبغات الطبيعية و المشتتة. تمت معالجة نسيج أسيتات السيليلوز بتركيزات مختلفة من جزيئات نانو ثاني أكسيد التيتانيوم (0.3-1.0٪) باستخدام تقنية النقع و العصر ثم معالجتها حراريا عند 110 درجة مئوية لمدة 5 دقائق أو عن طريق تعريضها لموجات الميكروويف لمدة 60 ثانية. تمت طباعة أسيتات السيليلوز المعالج بكل من الصبغة المشتتة (*C. I. Disperse Red 167*) و كذلك صبغة الكركم الطبيعية. تم تقييم قابلية طباعة نسيج الاسيتات المعالج من خلال قياس شدة اللون (*K / S*) بالإضافة إلى خصائص الثبات اللوني. أظهرت النتائج أن العلاج باستخدام *TiO2 NPs* في الوسائط الكحولية وكذلك الليزر / *TiO2 NPs* أدى إلى تحسين قابلية طباعة نسيج الاسيتات بكل من الصبغات المشتتة والكركم. أدت المعالجة بجزيئات النانو في محلول الإيثانول بتركيز 50٪ للنسيج المعالج مسبقا بموجات الليزر إلى الحصول على أعلى شدة لون وأفضل قيمة للثبات اللوني. يوفر استخدام صبغة الكركم وكذلك التشعيع بالليزر إمكانات عالية لتعزيز قابلية طباعة نسيج أسيتات السيليلوز بالصبغات الطبيعية ويوفر تقنية مستدامة وصديقة للبيئة كبديل للصبغات المشتتة.

الكلمات المفتاحية: سيليلوز أسيتات، صبغة طبيعية، ليزر، جسيمات نانو، ثاني أكسيد التيتانيوم، كحول