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Nano TiO_2 Provides Multifunctional on Dyed Polyester Fabrics with Enaminone-Based Disperse Dyes

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Abstract

We treated dyes polyester fabric with dispersion dyes we prepared before and after treating the fabric with titanium oxide TiO_2 nano-particles NPs to increase self-cleaning and light fastness, and we noticed that these attributes were greatly improved. The effectiveness of the polyester fabric to block UV radiation has been tested.

Keywords: *Disperse dyes, Ultraviolet protection factor., polyester.*

1. Introduction

When exposed to ultraviolet radiation for an extended period of time, it is widely known that they inflict severe damage to the skin's sensitivity, for example. Textiles were previously employed to defend against UV damage, and some improvements to the thickness of these textiles were produced, but these adjustments were insufficient to improve the efficiency of textiles against UV radiation. As a result, the fabrics were treated to improve their UV protection effectiveness, which resulted in some significant improvements. To characterize the ability of tissues to defend them against UV damage, the term ultraviolet protection factor (UPF) was coined. Polyester textures provide UV protection and can be treated with natural and inorganic synthetics like as TiO_2 and ZnO. [1-21]. We investigated ZnO as a suitable and safe bright beam blocker in a prior work, and subsequently recommended it for use as a UV blocker when treating polyester materials dyed with disperse dyes that we had already synthesized. A variety of innovative disperse dyes that have been employed to colour polyester fabrics have been prepared in our previous study [14-17]. Polyester fabrics were treated with titanium dioxide nano-particles to improve self-cleaning capabilities and light fastness.

2. Materials and Methods

General method for the Synthesis of disperse dyes **1**-**6** which applied in this survey had been annotated in our published study [14-17].

Dyeing procedure

El-Mahalla El-Kobra Company, Egypt, provided scoured and bleached 100% polyester fabric. The disperse dyes **1**-**6**, a dispersion of the dyes were

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produced by dissolution of the appropriate amount of dyes (3% shades) in 2 ml DMF and then added drop wise with stirring to the dye bath (liquor ration 1:30) containing dispersing agent. The pH of the dye bath was adjusted to 5.5, and the wetted-out polyester fabrics were added. We performed dyeing by raising the dye bath temperature to 130°C at and holding it at this temperature for 60 min. After they were cooled to 50°C, the dyed fibers were rinsed with cold water and reduction-cleared (1 g/L sodium hydroxide, 1 g/L sodium hydrosulfite, 10 min, 80°C). The samples were rinsed with hot and cold water and, finally, air dried [4].

Photo-Stimulated Color Removal on Polyester

A total of 0.01 g/L of methylene blue was marked on both the treated TiO_2 NPs (1–3%) treated polyester and the untreated fabrics. The polyester fabrics were illuminated through exposure to an ultraviolet lamp for 12 hours [4].

Ultraviolet Protection Factor Measurement

It is worth noting that the ultraviolet protection factor is the capability of dyed polyester fabric to block ultraviolet, which was conducted in an ultraviolet visible spectrophotometer 3101[4].

Light fastness

The light fastness test was performed using a carbon arc lamp and continuous illumination for 35 hours in line with ISO 105-B02:1988 test method 9. The influence on the colour of the examined samples was measured using the blue scale

Treatment of fabrics

Pre-treatment

Fabric samples were soaked in a 10 g/l nonionic detergent solution (Hostapal, Clariant) for 10 minutes before being dispersed with TiO_2 NPs (0-2.5 percent w/w) for 15 minutes with gentle stirring. The materials were squeezed to eliminate excess dispersion before being dried in a 70°C oven for 10 minutes. The fabrics were queried for 3 minutes at 140 degrees Celsius. The fabrics were washed at 60 ºC for 15 minutes in an aqueous solution with a liquor ratio of 1:50 containing 3 g/l nonionic detergent solution (Hostapal, Clariant) [4].

Post-treatment

After dyeing, the fabric samples were soaked in a 10 g/l nonionic detergent solution (Hostapal, Clariant) for 10 minutes before being dispersed with TiO_2 nano particles (0-2.5 percent w/w) under gentle stirring for 15 minutes. The materials were squeezed to eliminate excess dispersion before being dried in a 70°C oven for 10 minutes. The fabrics were queried for 3 minutes at 140 degrees Celsius. The fabrics were washed at 60 ºC for 15 minutes in an aqueous solution with a liquor ratio of 1:50 containing 3 g/l nonionic detergent solution (Hostapal, Clariant) [4].

3. Results and Discussion

It is a great value to mention here that scheme 1 shows the chemical structure of the disperse dyes **1**-**6** used to dye the polyester fabrics [14-17].

3.1. Self Cleaning.

Table 1 shows that, for all dyes **1**-**6** except dye **3**, the treated polyester fabrics after the dyeing process with titanium dioxide nano-particles TiO_2 NPs (Post-treatment) performed better than the treated polyester fabrics before the dyeing process (Pre-treatment) in terms of colour removal. For all prepared dyes **1**-**6**, dye removal values for dyed and untreated materials were always lower than dye removal values for treated dyed fabrics.

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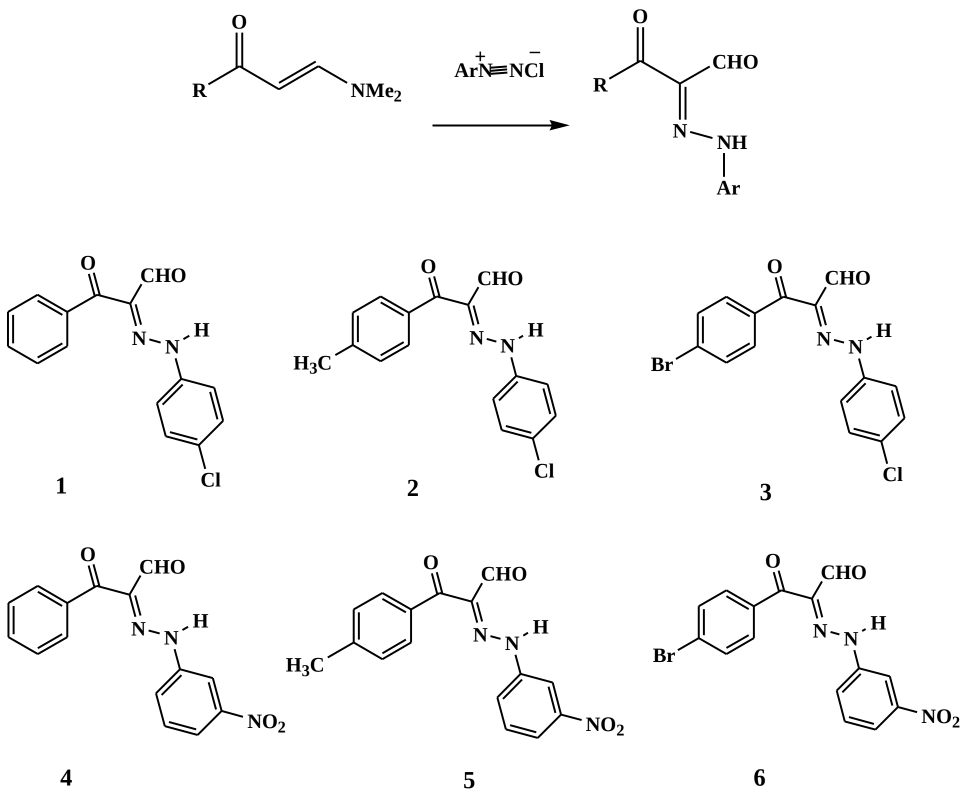

Scheme 1. Chemical structures of the disperse dyes 1-6

Table 1. Dye removal

Dye No	Treatment	TiO_2 %	Dye Removal	Dye No	Treatment	TiO_2 %	Dye Removal
	Untreated		50		Untreated		50
		1	30			1	40
	Pre-treated	2	30		Pre-treated	2	50
1		3	50	4		3	70
		1	50			1	60
	Post-treated	2	60		Post-treated	2	60
		3	60			3	50
	Untreated		50		Untreated		50
		1	40			1	60
	Pre-treated	2	50		Pre-treated	2	50
2		3	50	**5**		3	70
		1	50			1	60
	Post-treated	2	60		Post-treated	2	50
		3	60			3	60
	Untreated		50		Untreated		50
		1	50			1	40
	Pre-treated	2	60		Pre-treated	2	50
3		3	60	**6**		3	60
		1	40			1	60
	Post-treated	2	40		Post-treated	2	70
		3	50			3	60

Table 2. UPF of treated polyester fabrics

Dye No	Treatment	TiO2 %	AATCC Test Method 183 -UPF	AATCC - UVA Trans.	AATCC - UVB Trans	AATCC test method183 - UVA	AATCC test method183 - UVB
1	Untreated		738.4	0.1	0.2	99.9	99.8
	Pre-treated	1	836.0	0.1	0.1	99.9	99.9
		2	452.8	0.1	0.2	99.9	99.8
		3	773.5	0.2	0.3	99.8	99.7
	Post-treated	1	329.5	0.2	0.2	99.8	99.8
		2	308.3	0.1	0.2	99.9	99.8
		3	393.5	0.2	0.3	99.8	99.7
2	**Untreated**		396.0	0.2	0.3	99.8	99.7
	Pre-treated	1	377.3				
		2	394.1	0.2	0.3	99.8	99.7
		3	346.6	0.2	0.3	99.8	99.7
	Post-treated	1	285.7	0.2	0.3	99.8	99.7
		2	324.5	0.2	0.3	99.8	99.7
		3	259.5	0.3	0.3	99.7	99.7
3	**Untreated**		308.7	0.2	0.4	99.8	99.6
	Pre-treated	1	420.1	0.2	0.3	99.8	99.7
		2	340.8	0.2	0.3	99.8	99.7
		3	366.0	0.3	0.4	99.7	99.6
	Post-treated	1	353.6	0.3	0.3	99.7	99.7
		2	280.7	0.4	0.4	99.6	99.6
		3	375.4	0.3	0.3	99.7	99.7

Continue : **Table 2.** UPF of treated polyester fabrics

Dye No	Treatment	TiO2 %	AATCC Test Method 183 -UPF	AATCC - UVA Trans.	AATCC - UVB Trans	AATCC test method183 - UVA	AATCC test method183 - UVB
4	Untreated		277.8	02	0.4	99.6	99.8
	Pre-treated	1	316.9	0.2	0.2	99.8	99.8
		2	281.4	0.4	0.6	99.6	99.4
		3	261.4	0.5	0.6	99.5	99.4
	Post-treated	1	410.2	0.1	0.2	99.9	99.8
		2	366.3	0.2	0.2	99.8	99.8
		3	384.3	0.3	0.4	99.7	99.6
5	**Untreated**		380.4	0.2	0.3	99.8	99.7
	Pre-treated	1	1240.1	0.2	0.2	99.8	99.8
		2	595.7	0.1	0.1	99.9	99.9
		3	700.9	0.1	0.2	99.9	99.8
	Post-treated	1	1214.3	0.1	0.2	99.9	99.8
		2	708.1	0.2	0.3	99.8	99.7
		3	667.2	0.2	0.2	99.8	99.8
6	**Untreated**		220.1	0.5	0.4	99.5	99.6
	Pre-treated	1	430.9	0.3	0.4	99.7	99.6
		2	313.6	0.2	0.3	99.8	99.7
		3	355.8	0.3	0.4	99.7	99.6
	Post-treated	1	448.9	0.3	0.3	99.7	99.7
		2	166.1	0.2	0.2	99.8	99.8
		3	447.9	0.3	0.3	99.7	99.7

Table 3. Light fastness treated polyester fabrics.

Dye No	Treatment	TiO_2 %	Light Fastness	Dye No	Treatment	TiO_2 %	Light Fastness
	Untreated		3-4		Untreated		3
		1	4			1	3-4
	Pre-treated	2	2-3		Pre-treated	2	3-4
1		3	4	4		3	3-4
		1	3-4			1	4
	Post-treated	2	3-4		Post-treated	2	4
		3	3-4			3	4
	Untreated		5		Untreated		3
		1	3-4			1	4-5
	Pre-treated	2	3		Pre-treated	2	4-5
2		3	2-3	**5**		3	4-5
		1	2-3			1	3-4
	Post-treated	2	4		Post-treated	2	3
		3	4			3	3-4
	Untreated		3		Untreated		2-3
		1	2-3			1	2-3
	Pre-treated	2	3		Pre-treated	2	2
3		3	2-3	**6**		3	2
		1	2			1	4
	Post-treated	2	2		Post-treated	2	4
		3	2-3			3	3-4

In terms of treating polyester fabrics with titanium dioxide nano-particles TiO_2 NPs at a rate of 1 g/L, we discovered that the dye removal values of dyes **1**, **2**, **4**, and **6** in the treatment of polyester fabrics after the dyeing process with TiO_2 NPs are 50, 50, 60, and 60 percent, respectively, which is better than treating polyester fabrics before the dyeing process, where they were 30, 40, 40, and 40 percent. For dye **3**, the opposite happened, where the value of dye removal was 50% compared to 40%. For dye **5**, the value of dye removal was equal, as it was 60% for both methods. Regarding the treatment of polyester fabrics with titanium dioxide nano-particles TiO_2 NPs at a rate of 2 g/L, we discovered that for dyes **1**, **2**, **4**, and **6**, the dye removal values when treated polyester fabrics by TiO_2 NPs after the dyeing process were 60, 60, 60, and 70%, respectively, and that this was better than treated polyester fabrics before the dyeing process, which were 30, 50, 50, and 50%. For dye **3**, the opposite happened, where the value of dye removal was 60% versus 40%. As for the dyes **5**, the value of dye removal was equal, as it was 50% for both pre- and post-treatment methods, respectively. In the case of treating polyester fabrics with titanium dioxide nano-particles TiO_2 NPs at a rate of 3 g/L, we discovered that the dye removal values of dye **1**, **2**, and **6** were 60, 60, and 70% for treated polyester fabrics by TiO_2 NPs after the dyeing process, respectively, and better than treating polyester fabrics before the dyeing process, which was 50, 50, and 60%. Dyes **3**, **4**, and **5** had the opposite effect, with dye removal values of 60, 70, and 70 percent vs 50, 50, and 60 percent, respectively. When the best percentage of TiO_2 NPs was evaluated, the dye removal values for the produced dyes were the best. The optimal concentration of TiO_2 NPs is found to be 3 g/L.

3.2. Ultraviolet protection factor UPF.

In general, Table 2 shows that treating polyester fabrics with titanium dioxide nanoparticles TiO_2 NPs before the dyeing process (Pre-treatment) was better than treating polyester fabrics after the dyeing process (Post-treatment) for all dyes **1-6** except dyes **4** and **6**, where the opposite was true, and the UPF values for dyed fabrics and untreated fabrics were always lower than UPF values for treated dyed fabric for all prepared dyes **1-6** except dye **2**. In terms of treating polyester fabrics with titanium dioxide nanoparticles TiO_2 NPs at a rate of 1 g/L, we discovered that dyes **1**, **3**, and **5** performed better than treated polyester fabrics after the dyeing process with UPF values before performing the dyeing process with nano-titanium dioxide particles TiO_2 NPs at a rate of 1%. In the case of dyes **2**, **4**, and **6**, the exact reverse occurs. We found that the dyes **1**, **2**, **3**, and **6** were better than treating polyester textiles with nano-titanium dioxide particles TiO_2 NPs at a rate of 2 g/L, with UPF values before the dyeing process, than treating polyester fabrics with nano-titanium dioxide particles TiO_2 NPs. As for the dyes **4** and **5**, the exact opposite is happened. Regarding the treatment of polyester fabrics with nano-titanium dioxide particles TiO_2 NPs at a rate of 3 g/L, we find that the dyes **1**, **2**, and **5** were better than treating polyester fabrics with nano-titanium dioxide particles TiO_2 NPs with UPF values of UPF before performing the dyeing process. As for the dyes **3**, **4** and **6**, the opposite is happened. When determining which proportion of TiO_2 NPs generated the best UPF values for the prepared dyes, we discovered that 1 g/L of TiO_2 NPs is best for all dyes except dyes **2** and **3**, where 2 g/L of TiO_2 NPs is best.

3.3. Light fastness enhancement.

Table 3 shows that when treating polyester fabrics with titanium dioxide nanoparticles TiO_2 NPs at a rate of 1 g/L, the light fastness values in treating polyester fabrics before the dyeing process with TiO_2 NPs (Pre-treatment) for dyes **1**, **2**, **3** and **5** were ((4), (3-4), (2-3), (4-5), which is better than treating polyester fabrics after the dyeing process (Post-treatment), where they were ((3-4), (2-3), (2), and (3-4) respectively. For dyes **4**, **6** the opposite is happened where the value of light fastness was ((4-5), (4)) versus ((3-4), (2-3)). Regarding the treatment of polyester fabrics with titanium dioxide nano-particles TiO_2 NPs at a rate of 2 g/L, we discovered that the dyes **1**, **2**, **4** and **6** had light fastness values of ((3-4), (4), (4), (4), which is better than treating polyester fabrics after the dyeing process, where it was ((2-3), (3), (3-4) and (2), respectively. As for dyes **3**, **5** the opposite happened where the value of light fastness was ((3), (4-5)) versus ((2), (3)). Regarding the treatment of polyester fabrics with titanium dioxide nano-particles TiO_2 NPs at a rate of 3 g/L, we discovered that the light fastness values in treating polyester fabrics after the dyeing process with TiO_2 NPs for dyes **2**, **4** and **6** were ((4), (4), (3-4) respectively, which is better than treating polyester fabrics after the dyeing process, where they were ((2-3), (3-4), (2). As for dyes **1**, **5** the opposite happened where the value of light fastness was ((4), (4-5)) versus ((3-4), (3-4)). In the case of dye **3**, the light fastness value was the same (2-3) for both pre- and post-treatment techniques.

4. Conclusions

These disperse dyes **1**-**6** that were prepared by us provide value since their polyester colored fabrics perform well against harmful UV rays, and treating TiO_2 NPs is a simple, promising and easy way to make effective self-cleaning substrates that increase the light fastness property.

5. Conflicts of interest

There are no conflicts to declare.

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