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# Eco-Friendly Multi-Finishing Properties of Polyester Fabrics

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**Abstract**

THIS article gives an overview on self-cleaning technology on polyester fabric (PET) by titanium dioxide (TiO2), in a pure nano particle form. Titanium dioxide finishing develops several properties of the fabrics such as ultraviolet protection and anti-microbial finishing, and these finishings reduce energy, laundry cost and time. The article suggests the remedies such as the addition of an antistatic agent like sodium carbonate, acetic acid and TiO2, which are added to the base polymer. This treatment lowers surface resistivity to such a level that the static charge can easily get dissipated. In addition, the present work suggests printing the finished fabric with glow in the dark pigment (Strontium aluminate phosphors).

**Keywords:** Antistatic; Glow in dark; Screen printing; Self-cleaning; Titanium dioxide.

## Introduction

Technical textiles are high-performance smart materials created to improve quality of life while also adding a significant amount of additional functionality. They are used in contemporary civilization for a variety of specialised functions, including antibacterial, anti-insect, antistatic, and UV protection. [1-4] Nanotechnology is one of the most important new worldwide technologies, and self-cleaning with nanoparticles is one such technique. [5-8]

Fabric creation of electrostatic charge is a typical occurrence. Due to the material's interface quality, the phenomena of charge creation and transmission to the human body is more prevalent in textiles composed of polyester yarns. The production of the charge may cause the fabric's surface to gather dust, cause it to stick to the body, and even provide a painful shock. This condition is related to a number of factors, including the design of the fabric, the characteristics of the yarn, how it is finished, and the coatings that are applied to the yarn. Since seating is often made of polyester fabric, there have been several instances of seat fabric rubbing against human skin and producing static electricity.[9]

The primary role of an antistatic agent is to prevent generation of electricity within the different textile materials (Markus, et al., 1992). Polyester anti-static fabrics are mainly used in environmental protection and chemical industry. The characteristic of polyester anti-static fabric is high wear resistance, strong anti-static performance and great strength, because of its unique antistatic effect.

Antistatic finishes are typically used when the substrate's antistatic property has to be preserved for a longer period of time. The textile material can have an antistatic finish added by coating, finishing, or adding it to the polymer dope itself.

Synthetic fibers such polyester absorb less water because of which these are prone to building up static electricity.

Acetic acid and sodium carbonate have also reportedly been utilised to give synthetic fibres antistatic characteristics. [10, 11]

Nanoparticle self-cleaning of cloth has attracted amazing interest due to its unique properties. Because people are frequently affected by germs like bacteria,

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metal oxide-based nanoparticles are both non-toxic and disinfectants that can significantly reduce numerous microbial diseases. Due to their increased surface-to-volume ratio, metal oxide-based nanoparticles often exhibit outstanding physicochemical characteristics. [12]

One of the best self-cleaning nano particles is titanium dioxide ($TiO_2$). It is employed due to a number of benefits including non-toxicity, accessibility, affordability, chemical stability, and excellent physical and chemical qualities.Multi functions are obtained by titanium dioxide finishing like antimicrobial activity and ultraviolet (UV) protection properties. $TiO_2$ nanoparticles are also electrically conductive in nature and can be used to dissipate the static charge in fibers. [13]

As extremely significant photoluminescent pigments, lanthanide-doped aluminates have been widely used in the creation of photoresponsive materials for a variety of applications. Such uses include photo-patterning, chemo sensors, and anti-counterfeiting inks. Their quick response time, photo-switchable emission, and great reversibility are responsible for this. When exposed to UV light, lanthanide-doped aluminates have demonstrated an emissive colour shift.[14]

Pigment-binder paste is applied successfully onto (PET) fabric using screen printing technique followed by thermal fixation. [15]

In the present work, the authors aimed to finish polyester fabrics with titanium dioxide and anti-static agents to impart self-cleaning, anti-microbial and UV protection to fabrics, The static charges can easily get dissipated followed by printing with glow in the dark pigment (Strontium aluminate phosphors). The required tests are included and will be shown in detail.

## 2. Materials and Methods

### 2.1. Materials

- Polyester fabrics (polyester 100% / polyester soft 100% / polyester-organza) were kindly obtained from El-Mahala Company for Spinning and Weaving, El-Mahala (Egypt).
- Sodium carbonate anhydrous (soda ash) and Acetic acid 96% (pure reagent for analysis) are of laboratory grade, and were purchased from El-Gomhouria, Egypt.
- Titanium dioxide (nano powder, 21 nm particle size (TEM) $\geq$ 99.5% trace metals basis) was purchased from Sigma - Aldric, Egypt.
- The lanthanide-doped strontium aluminate ($SrAl_2O_4$: $Eu^{2+}$, $Dy^{3+}$) powder was produced in the lab using a high temperature solid-state process as described in the literature.[5-7, 14]
- Binder was purchased from El-Gomhouria, Egypt.
- Di-sodium hydrogen orthophosphate (reducing agent) was purchased from El-Gomhouria, Egypt.
- Thickener (Sodium alginate) was purchased from El-Gomhouria, Egypt.
- Urea was purchased from El-Gomhouria, Egypt.

### 2.2. Methods

- The prepared beakers for work were washed with 5% acetic acid and 100 ml distilled water.

#### 2.2.1. Treating the Substrates with Anti-Static Agents

Through padding baths, external antistatic chemicals are applied to the textile surface from solutions.

1. *Sodium carbonate:*

First, 100 ml of distilled water and 5 gm of sodium carbonate are put in a beaker and the solution is stirred. Second, 8 samples: (4 white samples / 4 printed samples) are put in the solution and heated by a hot plate and magnetic stirrer for 10 mins. at 45 ℃. After which, the samples are taken out of the beaker and are placed on a white paper to dry at room temperature for 5 mins. Then, the samples were put in the laboratory oven at 65 ℃ for 3 mins. Eventually, the samples are treated by sodium carbonate as an anti-static agent.

2. *Acetic acid 96%:*

First, 100 ml of distilled water and 5 gm of acetic acid are put in a beaker and the solution was stirred. Second, 8 samples: (4 white samples / 4 printed samples) are put in the solution and stirred well. Eventually, the samples were treated by acetic acid as an anti-static agent.

#### 2.2.2. Treating the Substrates with Titanium Dioxide Nano Particles

The nano particles of titanium dioxide ($TiO_2$Nps) (as it has multi functions) are used for making anti-microbial and UV protected fabrics and anti-static treatments as well.

3. ***Sample treated with sodium carbonate and titanium dioxide***

Additives: 5% Titanium dioxide + 30 ml distilled water + 3 drops dispersing agent.

- The treatment is carried on 8 samples (4 white samples / 4 printed samples).
- First, the samples are put in 8 metal tubes with piston caps and the weight of the samples is known. The appropriate concentration of titanium, distilled water and dispersing agent are put on them. Second, the samples are treated with nano $TiO_2$ by pad-dry-cure method, then the

tubes were put in a laboratory padder at a constant pressure for 2-3 hours. The treated samples are washed and dried in the laboratory oven at 65 °C for 3 mins. Eventually, the samples were treated by titanium dioxide.

4. ***Sample treated with acetic acid and titanium dioxide:***
- As mentioned before, the fabrics are treated with acetic acid and titanium dioxide the same.

**2.2.3. Printing the Finished Substrates with Glow in the Dark Pigment**
- Lanthanide-doped strontium aluminate:
- It is possible to create the $SrAl_2O_4$:$Eu^{2+}$, $Dy^{3+}$ complex by combining strontium (II) carbonate ($SrCO_3$), aluminium (III) oxide ($Al_2O_3$), europium (III) oxide ($Eu_2O_3$), and dysprosium (III) oxide ($Dy_2O_3$) in the following molar ratios: Sr: Al: Eu: Dy = 1:2:0.01:0.02 and adding 5% boric ($H_3BO_3$; molar ratio 0.2). The mixture is then suspended in 100 ml of 100% ethanol, followed by 20 minutes of ultrasonic dispersion at 25 kHz to achieve homogenous mixing. The resulting mixture is dried for 24 hours at 90 °C, ground for 2 hours in a planetary high-energy ball mill, and sintered for 3 hours at 1300 °C with a heating rate of 10 °C/min in a reducing environment of carbon dioxide. To achieve the required pigment that has been Eu2+ and $Dy^{3+}$ activated, the sintered product is re-milled and sieved.

**- Printing paste recipe:**

| | |
|---|---|
| Lanthanide-doped strontium aluminate | 3 gm |
| Binder | 3 gm |
| Di-sodium hydrogen orthophosphate (reducing agent) | 0.5 gm |
| Thickener | 6 gm |
| Urea | 2 gm |
| Distilled water | 60 ml |

- First, the printing paste recipes are put in a beaker and stirred well. Second, all white samples were printed and dried in the laboratory oven at 160 °C for 5 mins., (fixation). Eventually, the finished samples were printed with glow in dark pigment after.

**3. Measurements**

**3.1. Laboratory Testing of Antistatic Finish**

Through a number of techniques, including as padding baths, spraying, plasma grafting, vapour deposition, coating, and finishing, external antistatic chemicals are applied externally from solutions to the textile surface. Hydrophobic and hydrophilic functions are present in the molecular structures of external antistatic agents. Better ion mobility and dissipation arise from the hydrophilic component's orientation toward the air and promotion of moisture absorption. [11]

- Electrostatic clinging of fabrics can be obtained with AATCC 115 Test Method.
- Electrical resistivity of fabrics can be obtained with AATCC 76 Test Method [16]

**3.2. Self-Cleaning Test**
- TiO2 films that are self-cleaning go through two steps.:
  - a photocatalytic process that splits organic soil when it is exposed to UV light
  - Due to TiO2's hydrophilicity, water diffuses across the whole surface rather than clumping together, washing the dust.[17-19]
- By monitoring the rate at which methylene blue decomposes, the photocatalytic activity of polyester textiles that have been treated both before and after was evaluated (Aldrich, United States). Using a Cary Varian 300 ultraviolet-visible (UV-Vis) spectrophotometer in the wavelength range of 320-400 nm, the amount of ultraviolet transmission through textiles was measured. The performance of the photocatalytic self-cleaning was evaluated by observing the methylene blue degradation under visible light at wavelengths greater than 410 nm. Using a fluorescent lamp (TC-L18W, AC230V-50 Hz, China) at 5 cm and a light intensity of 44 W cm2, visible light irradiation was made possible.
- samples of polyester To achieve an adsorption/desorption equilibrium between the photocatalysis and methylene blue under ambient conditions, 1 g in 50 ml of an aqueous solution of methylene blue (10 mg/L at pH 6.5) were agitated for 30 minutes. After then, the samples were subjected to visible light radiation. A sample of 5 mL of solution was obtained after each interval of irradiation and examined using a spectrophotometer. By measuring the absorption maxima at 665 nm as a function of the irradiation period, the concentration of methylene blue was determined. The following equation was used to measure the photocatalytic degradation:

Photocatalytic degradation = $(C_0 - C_t/C_0)=(A_0 - A_t/A_0)$

Where $C_0$ is the original concentration of methylene blue, $C_t$ is the concentration at different irradiation time periods, $A_0$ is the initial absorption and $A_t$ is the variable absorption at different irradiation time periods.

**3.3. Ultraviolet Protection Activity:**

The UPF (ultraviolet protection factor) was calculated using the AS/NZS 4399:1996 standard methodology. AATCC 183:2010 UVA Transmittance was used to measure the ultraviolet transmission through the cloth using a Cary Varian 300 UV-Vis spectrophotometer.

**3.4. Performance of the Treated Fabrics' Antibacterial Barrier**

Using the disc agar diffusion technique, the antibacterial activity of polyester textiles was investigated. Staphylococcus aureus ATCC 6538-P (G+ve) and Escherichia coli ATCC 25933 (G-ve), Candida albicans ATCC 10231 (yeast), and Aspergillus Niger NRRL-A326 were the four representative test organisms employed (fungus). In the case of bacteria and yeast, nutrient agar plates were severely injected on a regular basis with 0.1 ml of 105-106 cells/ml. To assess the antifungal effects, 0.1 ml (106 cells/ml) of the fungal inoculum was planted into potato dextrose agar plates.

The inoculation plates were covered with 15mm-diameter textile-treated discs. To allow for maximal diffusion, plates were then maintained at a low temperature (4°C) for 2-4 hours. The plates were then incubated for the bacteria at 37°C for 24 hours and for the organisms to develop as much as possible at 30°C for 48 hours in an upright posture. The diameter of the inhibition zone, stated in millimetres, was used to measure the test agent's antimicrobial activity (mm). The experiment was run many times, and the average reading was recorded.

**3.5. Morphology and Chemical Composition Properties:**

The morphological analysis handled by Energy Dispersive Spectroscopy analysis (TEAMEDX Model) was investigated using a field emission scanning electron microscope (FE-SEM) on a Quanta FEG 250 (Czech Republic). On an LEICA DM2500 microscope, fluorescent optical microscope pictures were captured (EBQ 100-04). A JASCO spectrofluorometer model FP-8300 was used to analyse the printed polyester substrates' steady-state fluorescence emission spectra and excitation measurements. Since the fluorescence emission spectra were adjusted for the features of the emission monochromator and the detection photomultiplier response, the instrument immediately delivers corrected excitation spectra.

Excitation spectra were taken at fluorescence emission maxima and fluorescence emission maxima were used to record the fluorescence emission spectra. The UV irradiation source used was a UV lamp with a wavelength of =365 nm and a power of 6. On an LEICA DM2500 microscope, fluorescent optical microscope pictures were captured (EBQ 100-04).

**3.6. Colorimetric Measurements and Fastness to Light**

The colorimetric measurements were determined using Colorimetric screening Ultra scan pro (Hunter Lab; United States).

- A Konica Minolta CR-400 chroma metre with a D65 illuminant (daylight, colour temperature 6504 K), a 2° standard observer function, and an 8mm diameter illumination area was used to measure the colour of coated textiles before and after exposure to UV light. L* (lightness), a* (red/green), and b* (yellow/blue) are three-dimensional colour coordinates that were used to record the colorimetric measurements. L* supposes values between zero (darkest black) and 100 (brightest white), a* denotes red when positive and green when negative, and b* denotes yellow when positive and blue when negative.

In this test, textiles were exposed to UV light for 3 min using a UV lamp with a wavelength of 365 nm and a power of 6 W that was positioned 4 cm above the cloth. The UV lamp was taken out of the equation, and the colorimetric results were directly recorded. By using the high reflectance technique and the Kubelka Munk equation, the colour strength (K/S) was evaluated. According to ISO standards, the colorfastness to light was evaluated. **[20-22]**

**4. Result and Discussion**

**4.1. Laboratory Testing of Antistatic Finish**

Samples were treated with anti-static agents and the table shows the results.

In all samples which are pre-printed and treated with antistatic agents like (sodium carbonate and acetic acid), it was noticed that the colors became brighter.

Table 1: Surface resistance and the usefulness of finished antistatic fabrics.

| **Surface-resistivity range (Ω) a** | **Assessment** |
|---|---|
| 1 × 106 – 1 × 108 | Very good |
| 1 × 108 – 1 × 109 | good |
| 1 × 109 – 1 × 1010 | Satisfactory |
| 1 × 1010– 5 × 1010 | Limit of sufficiency b |
| s>5 × 1010 | Insufficient |

a- Normal climate with 65 % relative air humidity.
b- Need for more control and detailed specification.

**4.2. Self-Cleaning Test**

Samples were treated with titanium dioxide and the tables show the results.

Table 2. The photocatalytic self-cleaning performance of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and sodium carbonate as anti-static agents.

| **Polyester samples** | **Photocatalytic degradation Post-Treatment results (Å)** |
|---|---|
| Polyester 100% | 81 |
| Polyester soft 100% | 86 |
| Polyester organza fabric | 92 |

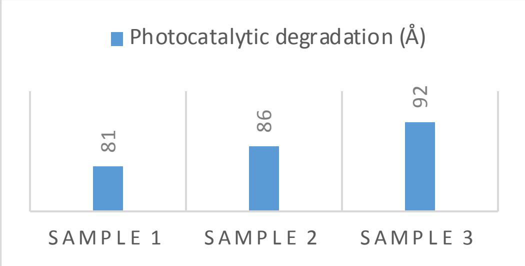


Fig.1: The photocatalytic self-cleaning performance of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and sodium carbonate as anti-static agents.

Table 3. The photocatalytic self-cleaning performance of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and acetic acid as anti-static agents.

| **Polyester samples** | **Photocatalytic degradation Post-Treatment results (Å)** |
|---|---|
| Polyester soft 100% | 77 |
| Polyester organza fabric | 79 |
| Polyester 100% | 90 |

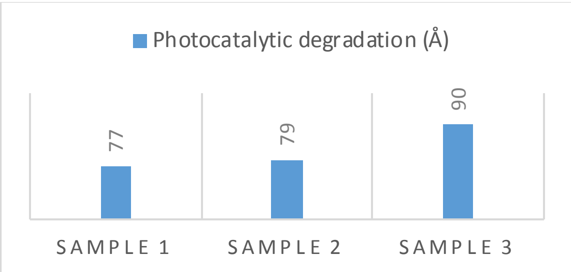


Fig.2: The photocatalytic self-cleaning performance of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and acetic acid as anti-static agents.

The dip-pad-dry-cure process is often used to create bonds between nanoparticles and a fabric (Chaudhari, et al., 2012).

In all samples which are pre-printed and treated with antistatic agents and Tio2, it was noticed that the colors faded and mixed with each other. Therefore, samples should not be printed before self-cleaning finishing.

The photocatalytic self-cleaning performance of polyester organza fabric which were treated with titanium dioxide nanoparticles and sodium carbonate as anti-static agents, gives best result.

### 4.3. Ultraviolet Protection Activity

Titanium dioxide imparts UV protection to fabrics, and the tables show the results.

Table 4. Ultraviolet Protection Factor (UPF) of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and sodium carbonate as anti-static agents.

| **Polyester samples** | **Ultraviolet Protection Factor (UPF) Post-Treatment results** |
|---|---|
| Polyester 100% | 178 |
| Polyester soft 100% | 195 |
| Polyester organza fabric | 76 |

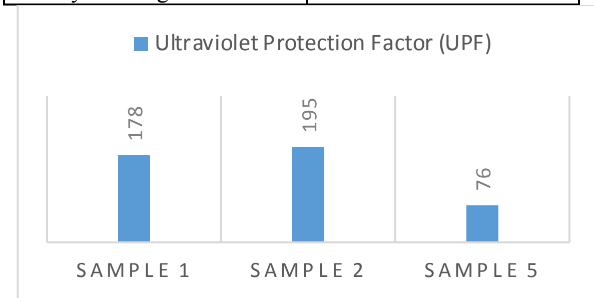


Fig.3: Ultraviolet Protection Factor (UPF) of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and sodium carbonate as anti-static agents.

Table 5. Ultraviolet Protection Factor (UPF) of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and acetic acid as anti-static agents.

| **Polyester samples** | **Ultraviolet Protection Factor (UPF) Post-Treatment results** |
|---|---|
| Polyester soft 100% | 176 |
| Polyester organza fabric | 201 |
| Polyester 100% | 85 |

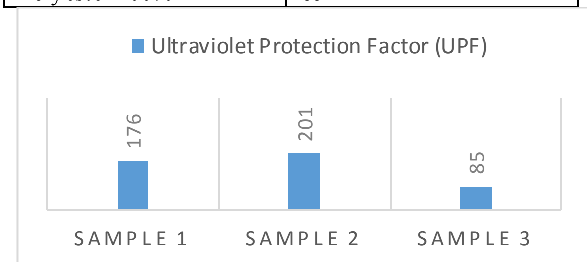


Fig.4: Ultraviolet Protection Factor (UPF) of different kinds of polyester samples which are treated with titanium dioxide nanoparticles and acetic acid as anti-static agents.

Ultraviolet Protection Factor (UPF) of polyester organza fabric which were treated with titanium dioxide nanoparticles and acetic acid as anti-static agents, gives best result.

### 4.4. Antibacterial Performance of the Treated Fabrics

Titanium dioxide imparts antibacterial performance to fabrics, and the tables show the results.

Table 6: Different types of polyester textiles' ability to inhibit the growth of test microorganisms include G+ve bacteria (S. aureus), G-ve bacteria (E. coli), Yeast (C. albicans), and fungal (A. niger).

| Serial no. | Polyester fabrics | Clear zone (ϕmm) | | | |
|---|---|---|---|---|---|
| | | S. aureus | E. coli | C. albicans | A. niger |
| 1 | Polyester soft 100% (AA) | 0 | 0 | 0 | 0 |
| 2 | Polyester 100% (SC) | 0 | 0 | 0 | 12 |
| 3 | Polyester soft 100% (SC) | 0 | 0 | 0 | 12 |
| 4 | polyester organza fabric (AA) | 15 | 0 | 12 | 0 |
| 5 | polyester organza fabric (SC) | 0 | 0 | 0 | 0 |

(SC) Treated samples with sodium carbonate as an anti-static agent.
(AA) Treated samples with acetic acid as an anti-static agent.

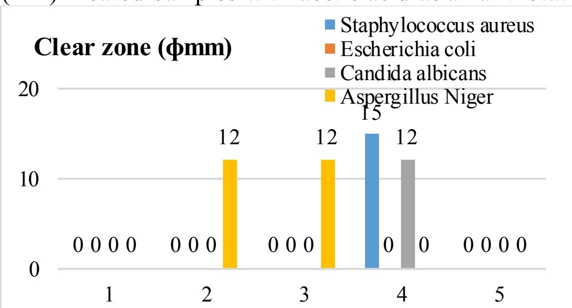


Fig.5: The antimicrobial activity of different kinds of polyester fabrics against different test microbes representing G+ve bacteria (S. aureus), G-ve bacterium (E. coli), Yeast (C. albicans) and fungi (A. niger).

- The antimicrobial activity of polyester organza fabric (AA) against different test microbes representing G+ve bacteria (S. aureus) and Yeast (C. albicans), gives best result.

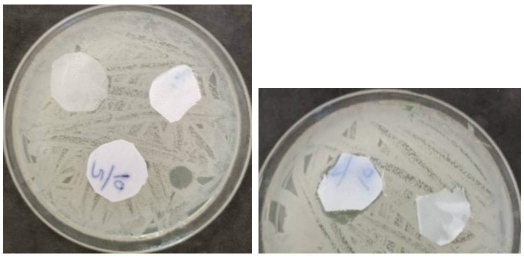

*Fig.6: samples: 1, 2, 3, 4, 5 with S. aureus*

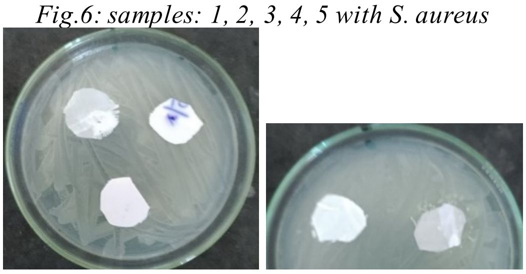

*Fig.7: samples: 1, 2, 3, 4, 5 with E. coli*

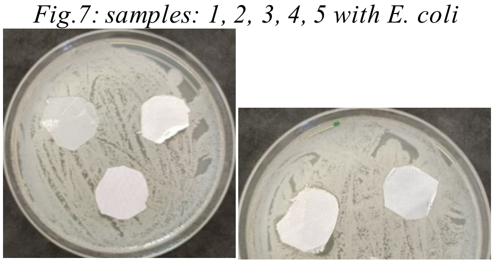

*Fig.8: samples: 1, 2, 3, 4, 5 with C. albicans*

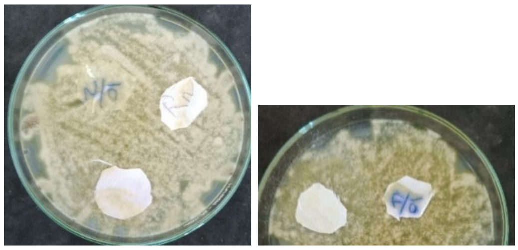

Fig.9: samples: 1, 2, 3, 4, 5 with A. niger

**4.5. Morphology and Chemical Composition Properties:**

Figures show SEM-EDX spectra that demonstrate the titanium element's presence and prove the incorporation of $TiO_2$ nanoparticles into the surface of polyester fabric (example: polyester organza fabric (SC)).

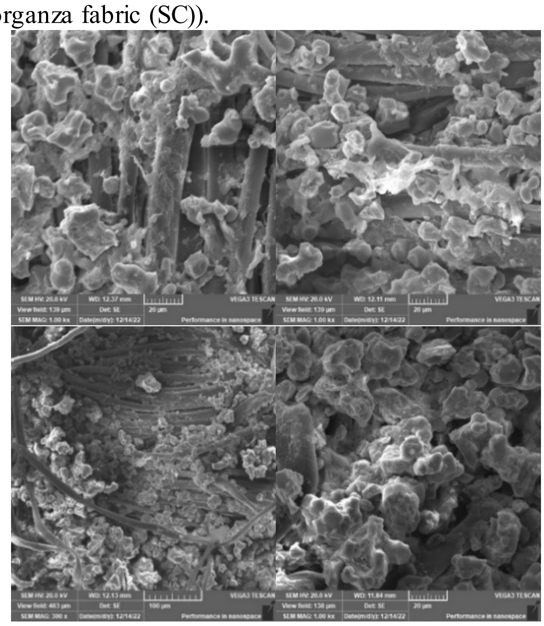

Fig.10: Scanning electron microscopic analysis.

**4.6. Colorimetric Measurements and Fastness to Light:**

The samples were printed with glow in the dark pigment (lanthanide - doped strontium aluminate), and Photographs of cell show the results under UV rays.

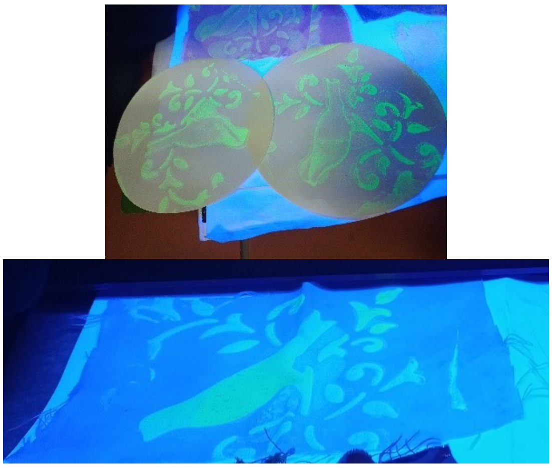

Fig.11: hotographs of cell after UV (λ=365 nm) excitation for 3 min at room temperature

## 5. Conclusion

In summary, the fabrics were treated with antistatic agents namely sodium carbonate, acetic acid and $TiO_2$. Titanium dioxide nanoparticles was prepared and applied to polyester fabrics before and after running the printing process. By treating the textiles, it was possible to improve their hydrophobic performance, which in turn improved the photocatalytic self-cleaning activity, improved the antibacterial performance, and increased the UV protection activity. The fabrics also were printed with glow in dark pigment (Strontium Aluminate). This glow-in-the-dark material continues to emit a strong green-yellow light after absorbing light for a while even when there is no light source present. For the polyester fabric, the morphological characteristics, elemental analysis, and mechanical measures were discussed. Finally, we described a new method to produce eco-friendly printed smart textiles with multifunctional properties.

## 6. Conflict of Interest

There is no conflict of interest in the publication of this article.

## 7. Acknowledgment

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## التجهيز الوظيفي المتعدد الصديق للبيئة لأقمشة البوليستر

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**الملخص**

تقدم هذه المقالة نظرة عامة على تقنية التنظيف الذاتي على أقمشة البوليستر (PET) بواسطة ثاني أكسيد التيتانيوم ($TiO_2$) ، في شكل جزيئات نانو نقية. يطور تشطيب ثاني أكسيد التيتانيوم العديد من خصائص الأقمشة مثل الحماية من الأشعة فوق البنفسجية والتشطيب المضاد للميكروبات ، وهذه التشطيبات تقلل الطاقة وتكلفة الغسيل والوقت. تقترح المقالة علاجات مثل إضافة عامل مضاد للكهرباء الساكنة مثل كربونات الصوديوم وحمض الخليك و $TiO_2$ ، والتي تضاف إلى البوليمر الأساسي. يقلل هذا العلاج من مقاومة السطح إلى مستوى يمكن أن تتبدد فيه الشحنة الساكنة بسهولة. بالإضافة إلى ذلك ، يقترح العمل الحالي طباعة النسيج النهائي مع توهج في الصبغة الداكنة (سترونتيوم ألومينات الفوسفور).

**الكلمات الدالة** : الاستاتيكيه ، يتوهج في الظلام ، طباعة الشاشة ، التنظيف الذاتي ثاني أكسيد التيتانيوم.