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Designing and Developing the Self-Cleaning Property of Drivers' Dress Using TiO_2 Nanoparticles

Taiebeh Asgharian-Dastenaie[a], Ali Nazari[a]*, Sayed-Javad Derakhshan[b]

[a]*Department of Art and Architecture, Yazd Branch, Islamic Azad University, Yazd, Iran*
[b]*Department of Cloth and Design, Yazd Branch, Islamic Azad University, Yazd, Iran*

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Abstract

Considering increasing development of nano-technology science and its wide use in most industries, textile industry was not excluded and manifested its capability in all fields accompanied with other sciences and achieved remarkable progress. Since interdisciplinary scientific research causes developing sciences and is attended by many specialists, in this research a beneficial step was provided applying dress design and textile chemistry sciences for more productivity of interdisciplinary discussions. In this study, the design of the drivers' uniform and their self-cleaning property were analyzed. In a way that; first, cotton fabric samples were treated using TiO_2 nanoparticles and poly carboxylic agent. Then, cotton fabric self-cleaning amount were evaluated and optimized. Based on the obtained results, drivers' uniform design with self-cleaning property against chemical and natural stains was gained, utilizing optimized amounts of TiO_2 nanoparticles. Therefore, the dress design applying nanotechnology discussions was effectively capable of having self-cleaning property in order to discolor natural color stains like tomato, sour cherry water, chocolate milk, gasoil, grease, oil, and chemical blue (C.I. Reactive Blue 19) and green (C.I. Direct Green 1) regarding scientific principles.

Keywords: Dress Design; Drivers; Self-Cleaning; TiO_2 Nanoparticles

* Corresponding author. Tel: +98-9132742611.
E-mail address: a.nazari@iauyazd.ac.ir.

1. Introduction

Dress design with a self-cleaning property is a significant and remarkable topic in garment industry because of sunlight irradiation as discoloring chemical and natural stains. Self-cleaning is obtained in dress surface and as a result of sunlight (Bozzi et al., 2005; Euvananont et al., 2008). The aim of self-cleaning in dress is to remove stains without utilizing detergent and only by sunlight. In recent years, applying TiO_2 nanoparticles in fabrics has been one of the best options for creating interesting and variant functions in dress (Bozzi et al., 2005; Yang, 2004). The activity of TiO_2 nanoparticles is due to the high ratio of surface to volume, which significantly shows discoloration activity under sunlight (Behzadnia et al., 2014). Lately, discoloring activity of solo phenyl Red GBL chemical stain and black mulberry natural stains has been evaluated, optimized, and statistically analyzed in treated acrylic carpets utilizing TiO_2 nanoparticles (Nazari et al., 2014). Also, self-cleaning property using other materials accompany with TiO_2 (Sangchay, 2016; Yuranova et al., 2007) and ZnO (Stieberova et al., 2017) nanoparticles has been reported to promote self-cleaning. Besides, accomplishing pretreatments like enzymatic treatment has been studied in order to enhance the self-cleaning property of cotton fabrics to remove C.I. Acid Blue 113 chemical stains (Montazer & Seifollahzadeh, 2011). However, there has been no report up to now related to simultaneous consideration of the two aspects, i.e., aesthetic discussions and dress design principals, and also its incorporation with engineering activities including discoloring of chemical and natural stains. As a result, the extracted information related to dress design especially drivers' dress is inadequate and most of the drivers' dress designs have been performed as a copy and without any originality. In fact, there is not enough attention to drivers' essential necessities when designing their dress. Therefore, in this research, it is tried to provide and obtain discoloring property for removing natural stains of tomato, sour cherry water, chocolate milk, gasoil, grease, oil, and green and blue chemical stains applying appropriate concentrations of TiO_2 nanoparticles and poly carboxylic stabilizing agent on cotton fabric; following that, the drivers' dress design was dealt with considering scientific principals and fashion through new and absorbing aesthetic designs.

2. Materials and Methods

2.1. Materials

Compounds and materials utilized in this research study include 100% cotton fabric from Ghaemshahr textile company, citric acid, sodium hypophosphite, sodium carbonate, sodium hydroxide, sodium silicate from German Merck company, TiO_2 nanoparticles with anatase crystalline structure from Degussa German Company, green chemical dye (C.I. Direct Green 1) and blue (C.I. Reactive Blue 19) from Bayer German company and natural dyes which were naturally purified and prepared.

2.2. Equipment

Electron scale with 0.0001 gram accuracy (Japan), ultrasonic bath with specifications 200 V, 50 W, 40 KHz (China), and the oven device were prepared. Scanning Electron Microscopy (SEM) with VEGA // TESCAN –XMU, Czech specifications was provided to observe the treated cotton fabrics with different magnifications. Reflectance Spectrophotometer device was provided from Germany with specifications of color-guide sphere, D/10°spin.

2.3. Method

Washed and bleached cotton fabrics were utilized in this study. The washing treatment was firstly accomplished using 3.0 % (based on weight fabric: O.W.F.) nonionic detergent, 10.0% (O.W.F.) sodium carbonate at 60ºC for 20 min. Afterwards, cotton fabrics were rinsed several times in order to demolish alkaline environment and disappear alkaline effects. Then, cotton fabrics were dried at environment temperature. Bleaching treatment was performed in a bath containing 3.0 % (O.W.F.) sodium hydroxide, 10.0 % (O.W.F) sodium silicate, 10.0% (O.W.F) hydrogen peroxide at 90ºC for 60 min and neutralizing treatment was performed through rinsing several times and then dried at environment temperature. To immerse cotton fabrics with TiO_2 nanoparticles, first different concentrations of TiO_2 nanoparticles (0.20, 0.85, 1.15, 1.50 %) were separately prepared based on weight bath (O.W.B.), 10.0 % (O.W.F) citric acid, and 6.0 % (O.W.F.) sodium hypophosphite were suspended in ultrasonic bath at 30ºC for 20 min. Then, cotton fabrics were treated in the baths through the impregnating method with TiO_2 nanoparticles at 60ºC for 30 min. Finally, cotton fabrics were dried via thermal oven at 100ºC for 15 min and at last were treated at 140ºC for 4 min. Therefore; washing treatment was performed using 2.0 % (O.W.F.) nonionic detergent, 5.0% (O.W.F) sodium carbonate at 50ºC for 10 min to separate non-stabilized nanoparticles. To measure self-cleaning amounts of treated fabrics, reflectance spectrophotometer device was applied. Then, treated cotton fabrics with different concentrations of TiO_2 nanoparticles were placed on flat surface, and 2 mL of each of natural and chemical stains were put on cotton fabrics using burette in similar conditions, and stains were dried on cotton fabric surface in environment temperature (Nazari et al., 2011). Finally, each of the stains was placed under sunlight irradiation for 6 hours and their discoloring property level was measured compared with controlled sample via evaluating color difference (ΔE) using reflectance spectrophotometer based on Eq.1 (Montazer & Pakdel, 2011).

$$\Delta E^{*} = \left[(\Delta a^{*})^{2} + (\Delta b^{*})^{2} + (\Delta L^{*})^{2} \right]^{1/2} \qquad (1)$$

The CIE Lab color system is widely utilized in color measurement of textiles (Jinlian, 2008). In this system, ΔL^* is the color lightness difference; Δa^* is red/green difference, and Δb^* is yellow/blue difference (Sharma, 2003). As it is observed in Equation (1), all color coordinates are considered in it and dE is affected by each of them. Therefore, Equation 1 could significantly measure color differences or color reduction of made chemical and natural stains. Besides, different papers have applied dE in order to measure self-cleaning amounts, while K/S in studies are mostly utilized in dyeability and absorption amount of dyes.

3. Comparative Investigation of Factors that promote Social Interaction in Religious and Cultural Spaces

3.1. Discoloring Amount of Chemical and Natural Colored Stains

Stains discoloring amounts of tomato (ΔE1), sour cherry water (ΔE2), chocolate milk (ΔE3), gasoil (ΔE4), grease (ΔE5), oil (ΔE6), and chemical green (ΔE7) and blue (ΔE8) created on different cotton fabrics treated with different amounts of TiO_2 nanoparticles and fixed amounts of citric acid 10.0% (O.W.F) and sodium hypophosphite 6.0 % (O.W.F) were measured and results were illustrated in Table 1.

Table1 Discoloring amounts of colored stains via cotton fabrics treated with different concentrations of TiO_2 nanoparticles under sunlight irradiation for 6 hours

Run	Nano TiO_2 (%)	ΔE_1	ΔE_2	ΔE_3	ΔE_4	ΔE_5	ΔE_6	ΔE_7	ΔE_8
Controlled	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
S-1	0.20	7.858	4.651	3.338	2.513	5.163	2.924	2.850	1.577
S-2	0.85	12.183	5.006	9.452	8.532	7.362	8.132	9.352	4.123
S-3	1.15	10.897	11.352	8.596	2.458	6.041	3.368	2.336	1.355
S-4	1.50	8.670	5.241	6.700	2.190	6.577	3.321	2.028	0.721

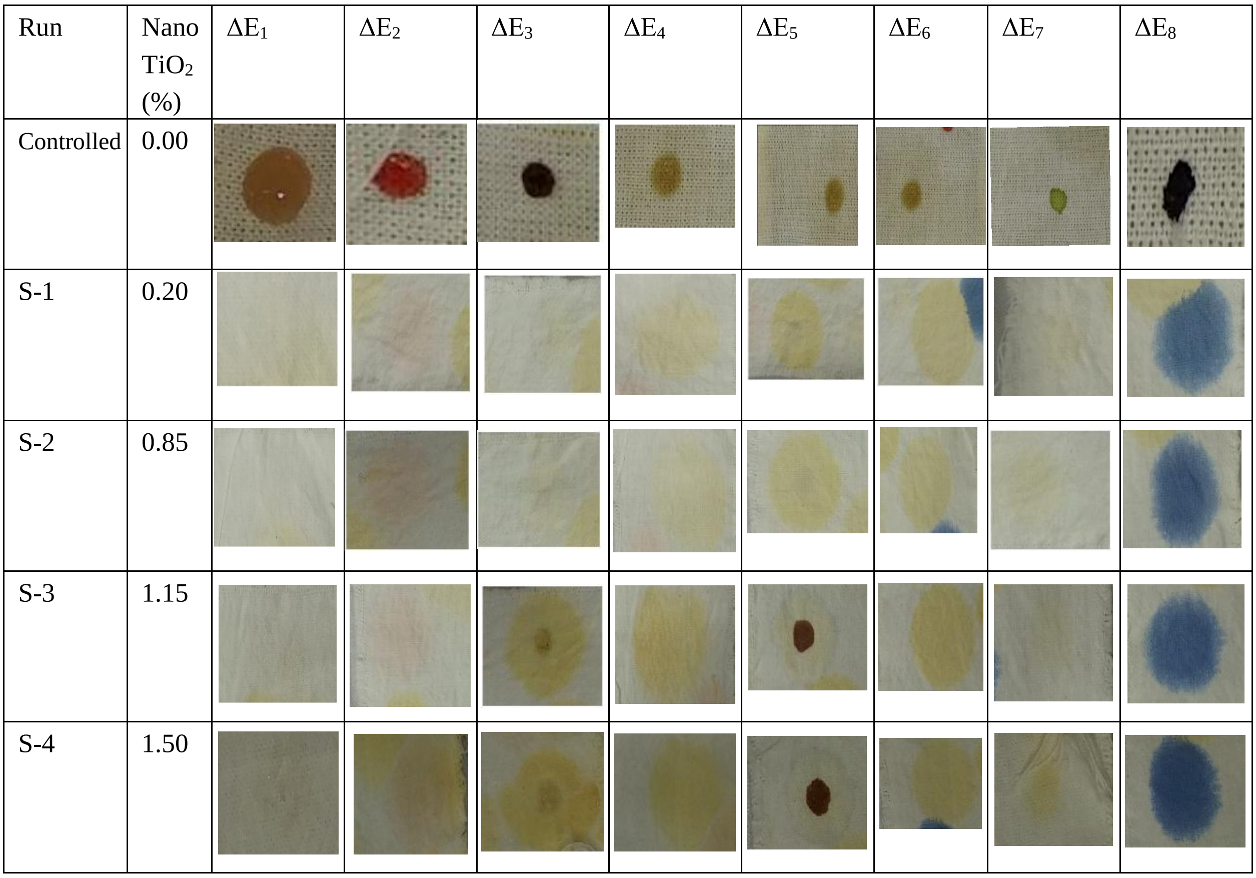


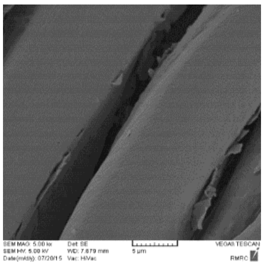
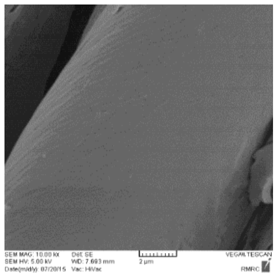
Fig 1 Discoloring images of colored stains through cotton fabrics treated with different concentrations of TiO_2 nanoparticles under sunlight irradiation for 6 hours

Also, images of stains that are likely to befoul drivers' dress such as tomato (ΔE_1), sour cherry water (ΔE_2), chocolate milk (ΔE_3), gasoil (ΔE_4), grease (ΔE_5), oil (ΔE_6), and chemical green (ΔE_7) and blue (ΔE_8) are presented in Fig 1. How natural stains of tomato, sour cherry water, chocolate milk, gasoil, grease, oil, and chemical green and blue were discolored through cotton fabrics with different concentrations of TiO_2 nanoparticles under sunlight irradiation is exhibited in Fig 1. As it is obtained from the results of Table 1 and images of Fig 1, cotton fabrics treated with TiO_2 nanoparticles could efficiently develop various degrees of discoloring than the controlled cotton fabric; cotton fabrics S-2 (containing 0.85% TiO_2 nanoparticles) were able to cause the highest discoloring amount of tomato (12.183), chocolate milk (9.452), gasoil (8.532), grease (7.362), oil

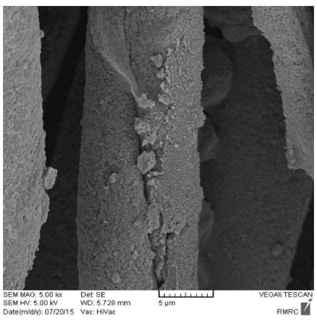
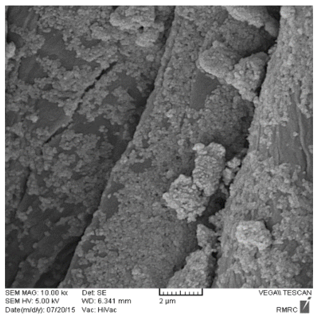
(8.132), chemical green (9.352), and blue (4.123). Further, cotton fabrics S-3 (containing 1.15% TiO_2 nanoparticles) could create the highest amount of discoloring of sour cherry water (11.352). This indicates that TiO_2 nanoparticles concentration less or more than 0.85-1.15% reduce the efficiency of discoloring, and the reason might be the insufficiency of TiO_2 nanoparticles concentration in making homogenous coverage of cotton fabrics and TiO_2 nanoparticles aggregation on cotton fabrics or inside the finish bath. Meanwhile, TiO_2 nanoparticles concentration about 1.0% could be reported as the most appropriate concentration to discolor natural and chemical stains. Although it should be considered that the highest discoloring amount is related to tomato natural stain and the least discoloring is related to blue chemical stain (C.I. Reactive Blue 19). The reason is supposed to be chemical structure and strength level of each colored stains connected to treated cotton fabrics. One of the basic advantages of this research is the discoloring study of a vast range of common natural stains by which drivers' dresses are likely to be dirty, while most of the recent applied research studies are related to discoloring of chemical stains with TiO_2 nanoparticles (Monzavi et al., 2017).

3.2. Scanning Electron Microscopy Images

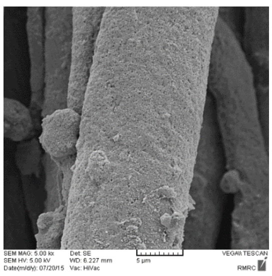
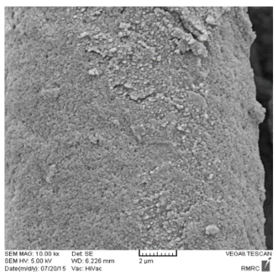
SEM images of controlled and treated cotton fabrics with different concentrations of TiO_2 nanoparticles and various magnifications are illustrated in Fig 2.

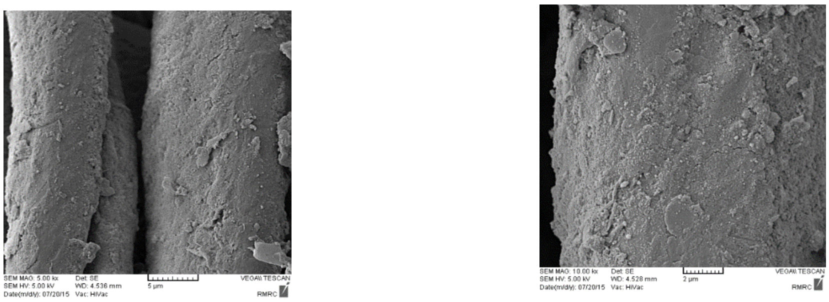
(a)

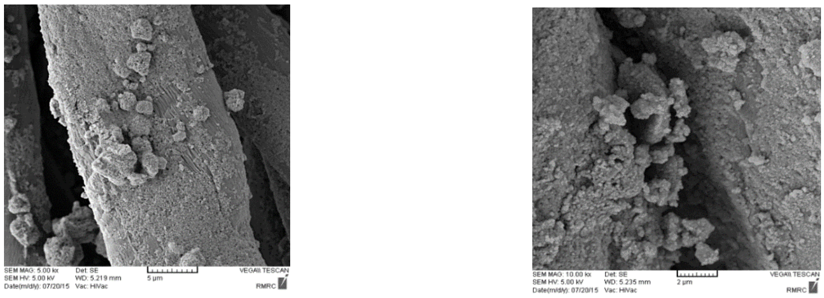
(b)

(c)



(d)



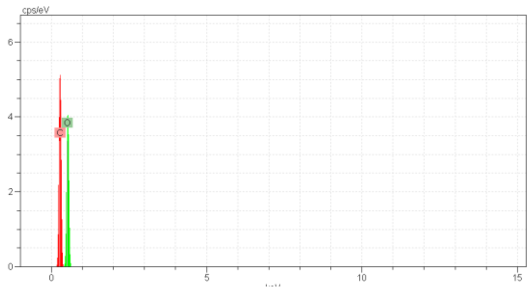
(e)

Fig 2 SEM images of controlled and different treated cotton fabrics including a- blank, b- S-1, c- S-2, d- S-3, e- S-4 with different magnifications ×5.000 and ×10.000

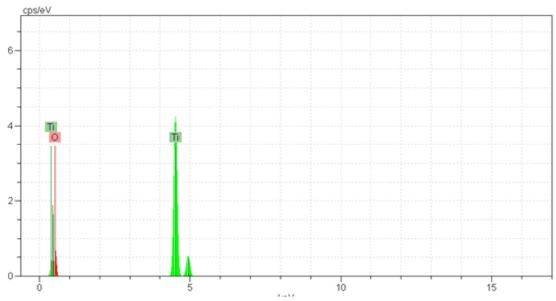
As it is shown in Fig 2-a, controlled cotton fabric has a flat surface and no particles are observed on it, whereas on the surface of other treated cotton fabrics, TiO_2 nanoparticles coverage is clearly observable. Because of the low concentration of TiO_2 nanoparticles (0.20%), the entire cotton fabric surface is not covered in Fig 2-a. An almost monotonous and regular coverage of TiO_2 nanoparticles is formed in Fig 2-c and 2-d. However, TiO_2 nanoparticles aggregation is observable which seems to be as a result of high concentration of TiO_2 nanoparticles (1.50%) in Fig 2-d. Since TiO_2 nanoparticles available on surface are exposed to ultraviolet irradiation of sunlight, active species such as electron and proton are produced. Developed active species hold the main responsibility of discoloring natural and chemical stains.

3.3. Energy Dispersive X-Ray (EDX) Spectroscopy

To determine Ti element available in treated cotton fabric as compared with controlled cotton fabric, EDX spectroscopy was utilized which is illustrated in Fig 3 (a, b). The technique confirms TiO_2 nanoparticles presence on the treated cotton fabric in a condition of 0.85% TiO_2 nanoparticles and 10.0% citric acid (Fig 3-b) as compared with the controlled sample (Fig 3-a). Hence, the peak related to TiO_2 nanoparticles is not observed in the spectra of the controlled cotton fabric. This technique is based on the fact that each element has a particular atomic structure which makes a possible exclusive collection of peaks in EDX spectra.



(a)
Energy (keV)



(b)
Energy (keV)

Fig 3 EDX spectroscopy of cotton fabrics (a) controlled, (b) sample S-2 containing 0.85% TiO_2 nanoparticles and 10.0% citric acid

3.4. Drivers' Dress Design

a. Uniform 1 Design

Design 1 is a two-part dress which consists of shirt and trousers (Fig 4). Bust is toughened to the trousers by a belt. On the belt, the left side of the dress, one accessory bag is devised in order for the easy accessibility to driver's personal accouterment like log book, document, and cell phone. For better visibility of drivers at night, reflective strips designed on different parts of dress are used which enhance the safety of drivers in darkness and emergencies. Reflective strips are designed in two sides, i.e., the trousers, and the front and back of the dress in breast line.

Fig 4 Uniform 1 Design

b. Uniform 2 Design

Uniform 2 is designed as two separated parts which include the bust and trousers. The bust is designed without sleeve for more convenience. The two separated bust and trousers are connected to each other via a belt in the waist. The front of the bust is covered by buttons. This kind of dress consists of belt, pocket, and hat. To facilitate the driver's job, pockets are designed in different parts. Two pockets in the breast line in front of the bust, one pocket on sleeve, two pockets in sides of the trousers and two pockets in the back of the trousers below the waist line.

Fig 5 Uniform 2 Design

c. Uniform 3, 4 and 5 Designs

Designs 3, 4, and 5 are stylistically similar to each other (Fig 6). Although all three forms are designed with one same model but they are different in cut and color. In the first one, as it is clearly observable, light color is utilized. Selecting light colors in drivers' dress depicts individuals full of positive energy; retaking constructive and positive energy from them makes the rest of the day more appealing, beautiful, and tolerable. Therefore, to set the dress and provide elegant appearance, the same color is applied in hat, head of the sleeve, and the cuts. The second form is designed with blue color. Blue is a kind of cold color which manifests special bravery and courage. Hat, pockets, cuts, and head of sleeves are selected as the dress color. In the third one, the impression is taken from the two previous forms and is designed for variety in drivers' uniforms. Light color is utilized in the bust for the main background and blue is used in the trousers. More, blue is used on the bust, in a horizontal cut on the breast line, head of sleeve, and hat. This leads to particular diversity and beauty. It should be mentioned that one red strip is used round of the wrists and part of the bust connection to dress in order to reduce the coldness of the blue color.

Fig 6 Uniform 3, 4, and 5 Designs

d. Uniform 6, 7 and 8 Designs

The model used in uniforms exhibited in Fig 7 is one-part design. This dress has a simple and special form. Individuals involved in crafts such as driving require an overall very much. Drivers' overall is a kind of cloth which the driver needs when problems such as tires blowing out, grease needing change or the seat belt being cut arise. Drivers are able to immediately wear this kind of overall upon their own dress when unexpected and immediate events happen in pathways or when taking care of the problems, therefore preventing their dress to be torn or become dirty; after finishing the repair job, they can easily unclothe the overall and continue driving.

Fig 7 Uniform 6, 7, and 8 Designs

As it is observed in Fig 7, three types of overall are designed for drivers. As it is illustrated, in all three forms, the clothes have stand-up collars. This kind of collar hinders entering pollution inside the body. Also in all of them, a zip is devised in front of the clothes to offer more convenience and quick wear.

4. Conclusion

Designing drivers' uniforms and optimizing their self-cleaning property were the aims of this research. Therefore, TiO_2 nanoparticles and poly carboxylic agent were applied to finish cotton fabrics. Colored chemical and natural stains on treated cotton fabrics were exposed to sunlight irradiation with different concentrations of TiO_2 nanoparticles. Based on the obtained results, the design for drivers' uniforms were achieved presenting efficient self-cleaning property against natural stains of tomato, sour cherry water, chocolate milk, gas oil, and chemical blue (C.I. Reactive Blue 19) and green (C.I. Direct Green 1) using optimized amount of TiO_2 nanoparticles. Applying nanotechnology could hence efficiently donate effective self-cleaning property against chemical and natural stains common in drivers' dress considering scientific principles, the drivers' basic necessities, fashion, and beautification aspects.

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