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Ultarvielote Protection of Cellulosic Fabrics

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Nowadays, there is a progressive increase in UV radiation on human skin caused by the depletion of the ozone in the earth's atmosphere. As long-term exposure to UV light can result in a series of negative health effects. Ultraviolet radiation is harmful to human skin and causes a variety of skin illnesses, which is an increasing worry for people all over the globe. Developing textiles with UV protection functionality has been widely researched up to now. Nanotechnology has developed several approaches for introducing UV-protected fabric by using semiconductor metal oxides. Ultraviolet-resistant cotton fabrics were developed by coating with ZnO and TiO_2 nanoparticles to increase the ultraviolet protection factor (UPF) to the fabric.

Keywords: UV radiation, Cotton fabric, UPF, Nanoparticles, UV absorbers.

Introduction

All treatments which give the textiles the properties of final use are included in the term "finishing" This may include visual, handling, and special features, including waterproofing and UV protection finishing, and so on. [1-6] And it can be classified into chemical and mechanical finishing. Chemical finishing can be defined as the use of chemicals to achieve the desired fabric property. It is also referred to as processes that change the chemical composition of the fabrics that they are applied to. [7-17]

Significant attention has recently been paid to textiles made for protective garments, particularly ultraviolet (UV) radiation protection. UV protection finishes are one of the most common chemicals finishing agents used on textile materials to protect humans and textile materials from the damaging effects of UV radiation. [18] Long-term UV exposure may contribute to skin worsening like as a toxicity effect of the skin, skin ageing, skin photo dermatosis, phototaxic allergies, skin reddening, skin darkening, skin cancer risks, eye damage (corneal opacification) to the damages to DNA. Solar radiation reaching the surface of the earth consists of light waves with a total wavelength from infrared to UV, Although the intensity of Ultraviolet photons in higher regions is much less than the visible or infrared radiation in a visible field, the energy per photon is considerably higher. [19] The very high energy absorbed by UV photons in the higher atmosphere, the direct damage caused by UV radiation to the human skin is a result of the wavelength of the radiation incident with the most damages caused by radiation below 300 nm. The actual skin danger wavelengths are 305–310 nm. The textiles supplied in the range of 300–320 nm must therefore be effective to shield the wearer from the UV sunlight. [18, 20] Physicists focused on the characteristics of the radiation have coined terminologies such as near UVs (290 - 400 nm), far UVs (180 – 290 nm), and vacuum vacuums (under 180 nm). The name UVA is between 320 and 400 nm, UVB is between UVC and UVA, from 290 to 320 nm, and UVC is below 290 nm, respectively.

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The ratio of the UV area to the total incident radiation is around five to six percent, and UVR quantum power to organic molecular bond energies is comparable. [19]

Effect of UV radiation on textile materials

One of the main causes of degradation of textile materials is UV radiation, which is due to excitation in some parts of the polymer molecule and a gradual loss of integrity, and depends on the nature of the fibres. Due to the very high-volume ratio of the surface, textile materials are susceptible to light and other environmental factors. Furthermore, the chemical structure of inorganic UV blockers, as well as their size, shape, crystallinity degree, and crystal form, all affect the protective mechanism. However, because UV blockers are primarily employed to protect the skin from UV radiation, their primary function when used in clothes is to prevent UV rays from passing through the textile material in both direct and indirect ways as shown in fig.1 [18, 21]. In the absence of UV filters, the loss in tensile strength appears to be greater in the case of nylon (100 percent loss), followed by wool, cotton, and polyester, with approximately 23, 34, and 44 % respectively. The penetration of UVR in nylon causes photo-oxidation and results in a decrease in elasticity, tensile strength, and a slight increase in the degree of crystallinity, Ultraviolet radiation has extensively been researched to raise public awareness of the adverse impacts of UV radiation on living biological organisms and different reporting methods, such as UV index, UPF and Sun Protective Factor (SPF) have now been introduced. [19, 22, 23]

The difference between SPF and UPF

Ultraviolet protection factor (UPF) is indicated for the protection extended with textile materials. UPF tests the amount of UV radiation that penetrates the skin. A textile UPF can penetrate the skin just (6.66%) in comparison to uncapped skin. It is the element that can prolong the duration of exposure to the sun without reddening the skin. [19, 20, 24]

The UPF is the measure of the performance of UVA and UVB radiation in textile safety. The ratio of UV transmission by air and UV radiation emitted by the textile is determined from the UPF following European standard EN 13758 Textile. [18, 22, 25]

The UV defence element reflects the ability of textiles to block and defend the wearer against UV rays. The ratio of redness on the skin, when exposed to the sun, is established. [19, 20, 26]

The sun protective factor (SPF) is a shielding factor against skin reddening, which is transmitted by radiation from the substance. The higher the SPF, the more the cloth protects against UV Radiation. In Europe and Australia, the SPF is referred to as the UV Protection Factor (UVF). The SPF is often used for so-called ‘sun-blocking skin creams, which indicates how long a person can be exposed to sunlight before skin damage. Usually, a fabric with an SPF of > 40 offers excellent protection from UV therapy. [22] If at each wavelength the device response is a linear dose function, then the following formula gives the (R) response by a wide spectrum. [27]

$$UPF = \frac{\sum_{290}^{400} E_{\lambda} x S_{\lambda} x \Delta_{\lambda}}{\sum_{290}^{400} E_{\lambda} x S_{\lambda} x \Delta_{\lambda} x T_{\lambda}}$$

where E_{λ} S_{λ} T_{λ} and Δ_{λ} are the relative erythemal spectral effectivenes, solar spectral irradiance in W^2 nm^{-1} spectral transmittance of sample and wavelength step in nm respectively.

$$UVR = (1/UPF) *100$$

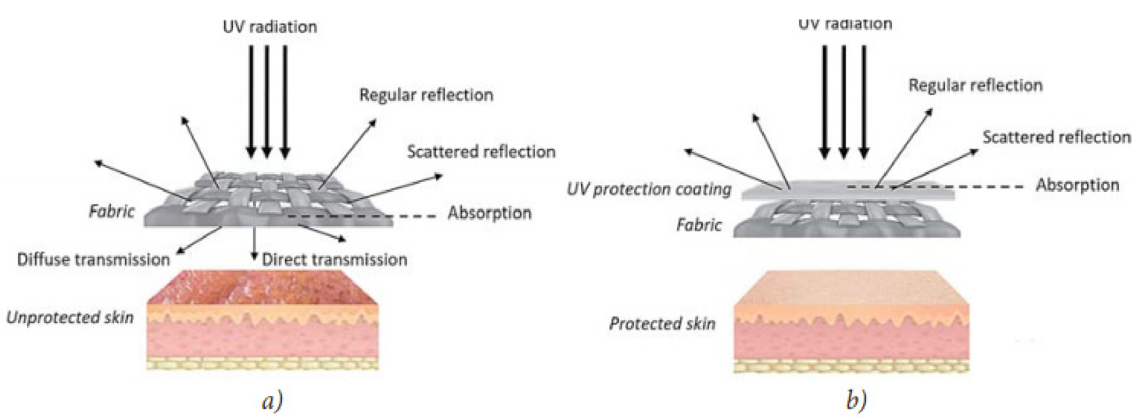

Fig. 1. Effect of UV radiation in the case of (a) the untreated and (b) treated fabrics[18].

$$R = \int_{t1}^{t2}\int_{\lambda 1}^{\lambda 2} \sigma(\lambda) I(\lambda, t) d\lambda dt$$

If λ is wavelength irradiance, t is time and σ ̈(λ) in cross-section to elicit such a response in wavelengths. The variations in the spectrum were protected by time as a radiation statement and as an integral component. [19, 28, 29]

UV protection on textiles can be achieved through various methods and techniques

UV absorbers are chemical compounds that are organic or inorganic that absorb UVB and UVA rays and return energy to the environment. The high UV energy is transformed as vibration energy in the absorbing molecule and atmosphere as heat energy. Different techniques such as padding, scraping, printing, dyeing, laying, etc. allow the application of UV absorbers to textiles. [22, 24]

Organic compounds

Compounds that are uncoloured organic aromatic molecules with conjugated double bonds have high absorption and their UV absorbers of 290–360 nm are integrated into the fibres which transform electronic excitation power to thermal power and then release to the surrounding environment when the molecules return to the ground state. Most organic UV absorbers are hydroxy benzophenone derivatives, hydroxy-phenyltriazin, hydroxy-phenyl hydrazine organically The ortho hydroxyl group is considered essential for the absorption and to make the compound soluble in alkaline solution. Bioproducts such as benzotriazole, hydrobenzophenone, and phenyl triazine are mostly applied in the padding and coating process to ensure broad UV protection. [7, 18, 19, 30]

Inorganic compounds

As a result of their non-toxicity and chemical tolerance when exposed to elevated temperatures and UV radiation, inorganic UV blockers are safer than organic UV blockers. Semiconductor oxides, such as ZnO and TiO_2, are the most common inorganic UV blockers. The nanoparticle sizes of ZnO and TiO_2 were longer stable and more efficient than their bulk sizes. [19, 26, 31]

Relationship between UPF and the nature of the fabrics

The UPF relies heavily on the chemical composition of the fibres in textiles. UPF differs in UV clarity due to the existence of these fibres. In addition to UV protective finishes applied to sun-protective clothing, special textile structures with the appropriate fibre type, yarn structure, fabric construction with low porosity and high cover factor, and the use of dyes that absorb radiation in the near UV region can significantly improve the UV protective properties of textiles. [18, 21] The absorption of natural fibres as cotton, silk, and wool is smaller than synthetic fibres such as PET. The grey cotton cloth has a higher UPF, as the main UV absorber are natural pigments, pectin, and waxes, while bleached fibre has high UV transparency. Raw natural fibres such as linen and hemp have a UPF of 20 and 10 to 15 respectively, not even with a lignin content being ideal UV protectors. The heavy absorption of jute, however, is caused by the presence of lignin as a natural absorber. The effect of protein fibres on UV radiation is also mixed. Dyed cotton fabrics have higher UPF and undyed cotton has very low UPF levels. In the 280-400 nm range and well above 400 nm, Wool absorbs intensely. Sun exposure damages the consistency, intensity, and durability of the silk in dry as well as wet conditions. Silk from mulberries is even worse than silk from mucous trees. Bleached silk and bleached PAN show very low 9.4 and 3.9 UPF. Polyester fibres absorb more from the aliphatic polyamide fibres in the UV A & UV B areas. [7, 19]

UPF is determined by the factor of covering, porosity, space, weight, fabric density. The greater the cover factor and the smaller the porosity, the higher the UPF, the greater width, weight, and density, the higher the UPF in the woven fabrics. The interlacing of loops is drawn during stretching so it allows UV rays to reach the gap. UPF depends also on the form of fibre. The greater is the UV defence for the full number of threads and strands in cotton. [22]

Dyes and UV radiation protection

Both dyes act as UV absorbers as the absorbing band spreads across the UV radiation spectrum (280-400 nm). Regardless of the fibre, darker dyes have greater protection against UV than pastel/ light dyes. However, in some UV degrees, each dye will differ considerably from protection based on their transmission and human absorption. The UPF can enhance certain direct, reactive, and vat dyes. Direct dyes enhance the UPF and natural dyes of bleached cloth They are also capable of improving the UPF to about 15-45 depending on the used mordant. [19]

The UPF also improves on cotton and cotton blends but not 100 percent nylon or polyester with optical illuminants. That was It Proven some natural herbs, for example, tea leaf, betel leaf, and Curry Leaf when added to the twill fabric of cotton; strengthen the textile UPF. [22]

Nanoparticles for ultraviolet protection in textile finishing

Conventional textile finishing procedures used to give cotton cloth distinct properties often do not lead to effective results and lose their purpose after laundering or usage. Though they have a wide surface area and high surface energy, nanoparticles may provide high durability for treated fabrics to enhance improved fabric affinity and contribute to increased durability of the desired textile feature. Due to the novel properties of semiconductors and metal nanostructures, their use in the textile finishing sector has grown significantly in recent years. [32-52]

The effects of blocking UV are demonstrated by several semiconducting materials, including TiO_2, ZnO, cerium dioxide (CeO_2). The materials include zirconium dioxide (ZrO_2.), magnesium oxide (MgO.), aluminium trioxide (Al_2O_3), silicon dioxide (SiO_2). TiO_2 and ZnO alone and in combinations are the most frequently studied UV blockers among these inorganic materials. [30, 53]

ZnO Nanoparticles in textiles

ZnO properties

There are three big benefits to ZnO's large variety of applications Zinc oxide (ZnO) is an inorganic semi-conductive substance with a strong interest in textile UV defence (widespread bandgap with a direct broadband distance of 3.37 eV and a high arousal capacity of sixty meV, The photocatalytic operation is an essential functional oxid, chemically stable, agreeable to the environment, more easily cultivated and longer-lasting ZnO is piezoelectric, a crucial feature for electromechanical coupling sensors and transducers, due to its non-centre symmetry. ZnO is also bio-safe, biocompatible, and can be used without coating for biomedical applications. [28] ZnO materials are favoured in nano sizes when used in ultraviolet protection finishing to improve endurance, absorption, and blocking in the UV field. Generally, ZnO NPs are generated by chemical synthesis or green synthesis with synthetic or natural materials from zinc sources such as zinc acetate, zinc chloride, and zinc nitrate. [7, 26, 53-58]

Chemical synthesis of ZnO nanoparticles

This research focuses on ZnO nanoparticles synthesized and characterized by a homogenous phase reaction between zinc chloride and sodium hydroxide at high temperatures. To determine the UV protective function in the treated textiles via standardized test procedures, nanoparticles of ZnO were then used on cotton and polyester/cotton fabrics. [26, 28]

There is another method to produce ZnO nanoparticles using Zinc acetate dissolved in H_2O_2 (3 %). The solution pH was adapted with ammonia dilute. the solution resulted in 100 c refluxed for 12 h, the nanocrystals produced at this point were cooled down at room temperature and were repeatedly laundered and centrifuged and ZnO-nanoparticles dried at 80 c for 3 h and nanopowder was produced by micro grinding equipment and the yield was found to be 36%. [7, 59]

Sol-gel method of coating fabric

Before the cloth has been sprayed, the moisture content has been dried in the oven. The cotton fabric was submerged into an aqueous nano solution with an acrylic binder. Nano solution was treated for fabrics with zinc-oxide nano solution and with a pad dry treatment process. Nanoparticles were coated evenly by laboratory padding mangle. After padding, it was dried for five minutes at 70°C and cured for 3 minutes at 120°C, and then we get the coated fabrics. [59, 60]

Linking agent technique

Samples of cotton were immersed in the presence of 4 % w/w sodium hypophosphite catalyst for 1 h and have been immersed in a 6 % w/w aqueous solution of crosslinking agent (succinic acid). The samples have been cured after drying at 90°C for 3 minutes. [59, 60]

Hydrothermal method

Prepared ZnONPs using water or ethanediol as a solvent and investigative hydrothermal method which is better. Sodium hydroxide increasingly has been incorporated (zinc chloride dissolved in water ethanediol). The particles resulting were processed thermally at 250°C and applied with a pad-dry cure technique to cotton and cotton/polyesters. Instead of water, 1,2-ethanediol was observed to result in smaller sizes of ZnONPs (between 20 and 9 nm) and higher UPFs both for UVA and UVB. It was observed that the smallest scale of ZnONPs, low concentration of chemical hazards (economically and ecologically), and high absorption spectrum of UV radiation have been given (235-407 nm). [26]

Green synthesis of ZnO nanoparticles

Green synthesis is better than chemical ZnONPs synthesis as its benefits from a clean, non-toxic, and eco-friendly finish. Green ZnONPs synthesis is based on the application of natural zinc-source materials. Prepared ZnONPs from the reaction of chemically modified (CMC), chitosan with zinc-nitrate. [61] The content of Chitosan is inexpensive, ecological, poisonous, and highly stable. modified Chitosan was prepared with the progressive addition of sodium chloroacetate by dispersing the chitosan in (50-75%) isopropyl alcohol, zinc acetate was added to the mixture and calcined at different temperatures. Modified chitosan was found to be more closely related to zinc ions than indigenous chitosan. and then we get a more uniform distribution and smaller size of ZnONPs. [26]

Green process prepared ZnONPs. Extract from the Citrus aurantifolia leaves (as a stabilizing and reducing agent) and zinc nitrate were used. The ZnONPs resulting Scale spectrum (9-10nm) and absorbed UV irradiation at the intervals were evenly distributed (208-400 nm). [26]

ZnONPs are made by the use of green materials (Aloe Vera) as stabilizing and reducing agents. The mixture of sodium hydroxide (Aloe Vera extract leaves and zinc acetate) was added gradually. The resultant ZnONPs are of average size (22.18 nm), have antibacterial action against gram-positive and gram-negative bacteria, and absorb UV rays within the range (340-400 nm). The synthesis of ZnONPs by Varghese is better than other approaches because they require fewer chemical components (only zinc source and natural materials). [26]

Application of ZnO NPs to cellulosic materials

ZnONPs are used for antibacterial and UV defence for cotton fabrics in combination with carboxymethyl chitosan. ZnO/carboxymethyl composite was produced by stirring at various temperatures, it has been observed that ZnO/CMC composite preparation resulted in a smaller NPs scale. Higher ZnO/CMCTS nanocomposite concentration improved antibacterial activity for all forms of S.aureus and E.coli. Higher UPF values were achieved. Treated cotton fabric samples displayed comparatively higher UPF values and anti-bacterial activity with higher chitosan/ZnO concentration. [60, 62]

TiO2 Nanoparticles in textiles

TiO2 properties

TiO2 is a transition metal oxide inorganic substance. In several fields of the textile industry, TiO_2 particles in nano form are used, in particular, for UV defence due to their characteristics (lower cost, chemically stability, non-toxicity, photocatalytic activity, and longer durability). [55]

Treated cotton fabric with TiO_2 nano sol imparted excellent UVR protection to the fabric of cotton, especially in the UVB region [290–315 nm]. It has been demonstrated that nano-particle TiO_2 cotton fabrics were found durable to domestic washes due to the creation of covalent bonds between the (OH) cellulose groups and the (OH) network titanium groups. Comparing the sol-gel process with the linking agent technique, the latter resulted in better results for both the undyed and dyed samples. The rutile crystalline phase was found to be more effective in UV protection. [7, 53]

TiO_2–SiO_2 by sol-gel processing synthesized. TiO_2/SiO_2 nanoparticles were better secured against UV than silica particles or untreated textiles. Besides, there was no photodecomposition effect on organic suspension materials on the coated nanoparticles. The experimental findings and technical approach suggest that the TiO_2/SiO_2 core-shell configuration is theoretically capable of blocking UV applications in textiles and toiletries while preventing effects on the organic substrate. [7, 53, 60]

Chemical synthesis of TiO2 nanoparticles

Titanium tetrachloride (TiCl4) was hydrolyzed by adding 1m ammonia dropwise to prepare a stock solution in which the concentration of titanium was 5.45 m. During the reaction, the yellow particles of TiO(OH)2 were formed first, which were then dissolved with added ammonia solution to form an aqueous TiCl4 solution. this stock solution remained in a stable state without precipitation even after 5 months at room temperature

Finally, an ammonia solution with a concentration of 4.5 m HNO_3 was added to the stock solution to prepare a transparent aqueous $TiCl_4$ solution with various concentrations of TiO_2 for precipitation. this solution was poured into the reactor and placed in the oven at 90°C for precipitation. TiO_2 precipitate was repeatedly cleaned by distilled water and dried at 80°C for 6 h. [7, 60, 63]

Coating TiO2 on the fabrics

TiO_2 nanoparticles, reactive and natural dye (henna extract) have been mixed using various methods to achieve fast protection from toxic UV radiation. Different dyeing and finishing formulations were exposed to cationized cotton utilizing reactive dyes and extract of Henna in combination with TiO_2 nano-sol. The treated fabrics demonstrated excellent and long-lasting UV safety without impacting other results. The content and the dyeing temperature of TiO_2 are controlled for improved UV safety. Doping of reactive dyes with TiO_2 nano-sol can be found to substantially alter the surface of the fibres. [7, 64-66]

However, there were different coating morphologies for the three different concentrations of TiO_2 nano sol. The more TiO_2 nano-sol is made, the greater the amount of TiO_2 nanoparticles in treated fibres and the greater the UPF. [7]

It may be found that, by raising the dyeing temperature, UPF values are improved, which increases the level of UV safety in dark shades obtained which can be considered to block and/or absorb harmful UV radiation to a greater degree. Growing laundering cycles results in a minor decrease in the UPF values of samples handled, dyed, and suggesting a strong adhesion from TiO_2 to the surface of the cloth. Absorption of the adsorbed TiO_2, and the transition of hydrogen from TiO_2 to cells and interactions (The longevity for the dyed fabric to the safety of the UV could be due to the creation of covalent relation between various hydroxyl groups of Cellulose and the hydroxyl Group TiO_2 networks. [7, 60]

Suspension of TiO_2 aqueous ultrasonicated. The 3:1 and 1:3 mixtures were used both as anatase and rutile forms. In this aqueous TiO_2 suspension, the binding agent samples were immersed and heated for 1 hour at 60°C. The TiO_2 was washed out after drying. [24, 60]

Green synthesis of TiO2 nanoparticles

Green synthesis of TiO2NPs depends on using natural materials and it is far better than chemical synthesis of TiO_2NPs as it depends on less hazardous chemicals and produces eco-friendly finishes.

TiO_2NPs synthesized using Aspergillus tubingensis soil fungus using an eco-friendly and low-cost process. To receive TiO_2 nano, a salt solution of TiO2 has been used in the soil fungi. The resulting TiO_2NPs were found to be of different sizes. The resulting TiO2 NPs demonstrated UV radiation absorption within the range (300-350 nm).

The TiO_2NPs were synthesized and tested for the photocatalytic function of the resulting NPs, using the leaf extracts of the medicinal plant Ageratina altissima. The TiO_2NPs resulting had an average dimension (60-100 nm), higher UV protection. [60]

Application of TiO2NPs after fabric treatment

The use of TiO2NPs in various processes in textiles enhanced UV defence and other functions as treatment fabrics increased affinity to finishing agents. [67] After treatment with H2O2, the TiO2NPs are applied on a cellulose acetate fabric (CA). samples have been padded in varying amounts of TiO2, dried, and cured in different conditions in microwave ovens. The following has resulted in increasing the whiteness and significant decrease of roughness and tensile strength of textile and higher UV protection. [60]

Summary

Avoiding sun exposure, although it is an inappropriate option for anyone, is the safest strategy to minimize UV exposure. The majority of people's substantial UVR exposures are at recreational exposure, and occupational exposure is also relevant. The interest in reducing the exposure to UVR by outdoor staff is rising. This involves the production of stronger UV absorbers that are specifically sufficient for low UPF fibres, where the user is particularly in favour. Recently, nanoparticles have been used to functionalize cotton fabric with UV protection. Numerous studies proved that cotton fabrics treated with TiO_2, ZnO nanoparticles showed outstanding and durable protection against harmful ultraviolet radiation. Comparing the sol-gel process with the linking agent technique for coating the nanoparticles into the surface of the cotton fabric, the latter resulted in better results for both the undyed and dyed samples. Likewise, the rutile crystalline phase was found to be more effective for UV protection. Comparing ZnO with TiO_2, the latter performed much better than the former. So, it is possible to substitute traditional methods of finishing to obtain high UV protection with the products and/or processes based on nanotechnology.

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Conflicts of Interest

The authors declare no conflict of interest

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المثخنات الصناعية في طباعة المنسوجات

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في الوقت الحاضر ، هناك زيادة تدريجية في الأشعة فوق البنفسجية على جلد الإنسان بسبب استنفاد طبقة الأوزون في الغلاف الجوي للأرض. نظرًا لأن التعرض طويل المدى للأشعة فوق البنفسجية يمكن أن يؤدي إلى سلسلة من الآثار الصحية السلبية. تعتبر الأشعة فوق البنفسجية ضارة بجلد الإنسان وتسبب مجموعة متنوعة من الأمراض الجلدية ، وهو ما يمثل مصدر قلق متزايد للناس في جميع أنحاء العالم. تم بحث تطوير المنسوجات بوظيفة الحماية من الأشعة فوق البنفسجية على نطاق واسع حتى الآن. طورت تقنية النانو العديد من الأساليب لإدخال النسيج المحمي من الأشعة فوق البنفسجية باستخدام أكاسيد المعادن شبه الموصلة. تم تطوير الأقمشة القطنية المقاومة للأشعة فوق البنفسجية من خلال الطلاء بجزيئات *ZnO* و *TiO2* النانوية لزيادة عامل الحماية من الأشعة فوق البنفسجية (*UPF*) على القماش.