

Design and characterization of self-cleaning cotton fabrics exploiting zinc oxide nanoparticle-triggered photocatalytic degradation

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Abstract Self-cleaning surfaces are functional structures with application in smart textiles. In this study, self-cleaning cotton fabrics were fabricated by coating photocatalytic zinc oxide nanoparticles (ZnO NPs) on cotton surfaces, using a traditional dip-pad-dry-cure coating process. The coatings and ZnO content-dependent self-cleaning properties of the coated fabrics were investigated to evaluate their potential in practical application. The ZnO NP-coated cotton fabrics were characterized by Fourier-transform infrared spectroscopy,

X-ray diffraction, field-emission scanning electron microscopy, and thermogravimetric analysis. Methylene blue was used as a test contaminant to qualitatively assess the self-cleaning properties of the fabrics. The removal efficiency was determined for fabrics with different ZnO contents, under different solar irradiation times. Consecutive photocatalytic degradations were carried out to investigate the self-cleaning durability of the fabrics. This involved repeatedly contaminating the same fabric position and subsequent cleaning by photocatalytic degradation. The self-cleaning properties of the fabrics depended on their ZnO NP content. A higher wt% of ZnO NPs in the coated fabric resulted in more pronounced photocatalytic degradation than fabrics with a lower wt%. The self-cleaning performance of the higher wt% ZnO NP fabric decreased slightly after the third consecutive photocatalytic degradation. Results of wash fastness showed color removal after 10 times washing under light irradiation. Moreover, the ZnO NP-coated fabrics exhibited excellent ultraviolet blocking properties. These findings provide a potential model for the practical application of self-cleaning textiles.

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Introduction

Rapid industrial development has led to increased energy demand. Conventional energy sources

constitute almost 80% of global energy consumption. This has led to energy shortages and environmental problems, especially in undeveloped countries (Mekhilef et al. 2011). The development and utilization of clean and renewable energy sources is attracting ever-increasing interest to supplement and/or replace traditional energy sources. Solar energy is abundant, free, clean, and renewable, and can be used directly or indirectly (Thirugnanasambandam et al. 2010). For example, solar batteries, solar water heating, solar ponds, and solar architectures are important for protecting energy and the environment. Global water shortages are another environmental concern. Reducing water consumption and pollution are topical concerns, given the increase in human population and development of modern industry. Outside of industrial and agricultural consumption, domestic wash water constitutes the highest water consumption. Decreasing the consumption of wash water is important for saving water and environmental protection. Strategies are therefore required for producing clear energy and decreasing water consumption.

Imparting fabrics with self-cleaning technology involves removing or degrading contaminants without washing, thereby saving water. Self-cleaning technologies can generally be classified as hydrophobic or hydrophilic (Ganesh et al. 2011; Parkin and Palgrave 2005). The former involves coating a hydrophobic layer on a fabric, so water droplets containing contaminants slide and roll off. Hydrophobic and superhydrophobic surfaces rely on highly ordered spatial structures. They are sensitive to organic solvents, in which conventional fluoropolymer-based hydrophobic agents tend to dissolve. The hydrophilic technique does not rely solely on the flow of water to remove contaminants. Rather, it exploits photocatalytic degradation, allowing water spread over the surface to carry away photodegraded organic contaminants. The construction of photocatalytic surfaces is not necessarily limited by solvent sensitivity, and so has better potential for practical applications than the hydrophobic technique.

A photocatalytic surface can be constructed by uniformly coating photocatalytic nanomaterials on the fiber surface. Exposing wide band gap semiconductor metal oxides to solar energy can chemically break down complex dirt deposits by photocatalysis. This technology is attractive because of its high catalytic

efficiency, low cost, and environmental sustainability (Zheng et al. 2007). Materials exploited as photocatalysts have included titanium dioxide (TiO_2) (Abidi et al. 2009; Bhattacharyya et al. 2010; Karimi et al. 2010; Qi et al. 2006; Rahal et al. 2011; Wu and Long 2011), zinc oxide (ZnO) (Çakır et al. 2012; Chandrappa and Venkatesha 2012; Ghayempour and Montazer 2017; Hatamie et al. 2015; Kenanakis et al. 2012; Manna et al. 2015; Tian et al. 2012), and tungsten trioxide (WO_3) (Adhikari et al. 2015; Shafaei et al. 2016). While TiO_2 has clearly received the most attention in photocatalysis research, ZnO is a promising alternative because of its large band gap (3.37 eV), large exciton binding energy (60 meV), lower cost (Hernández-Alonso et al. 2009; Kanmani et al. 2012), and biocompatibility (Barnes et al. 2013; Moore et al. 2014). ZnO is also cheaper (Hernández-Alonso et al. 2009) and exhibits better ultraviolet (UV) shielding and antibacterial properties (Barnes et al. 2013) than other photocatalysts such as WO_3 . The practical application of ZnO in self-cleaning fabrics was therefore investigated in the current study.

Previous studies have coated ZnO nanoparticles (NPs) on natural or artificial fibers for self-cleaning applications (Çakır et al. 2012; Ghayempour and Montazer 2017; Height et al. 2006; Ma et al. 2011; Manna et al. 2015; Moafi et al. 2011; Shirgholami et al. 2014). However, among these literatures, discussions were focused on the self-cleaning property for only one time. Actually, for textiles, it will be stained on the same place for more than once. Therefore, it is necessary to discuss the durability of self-cleaning performance by stained fabrics for several times, which had been investigated little in previous studies. Moreover, the systematic study on the ZnO content-dependent self-cleaning performance can be considered as reference resources for the practical applications in the future. Therefore, in this study, self-cleaning cotton fabrics exploiting ZnO NP-triggered photocatalytic degradation were fabricated using a traditional dip-pad-dry-cure coating process. Their coating structures and ZnO content-dependent self-cleaning properties were investigated, to evaluate their potential in practical application. The structure, crystallinity, morphology, and decomposition of the coated cotton fabrics were investigated by Fourier-transform infrared (FTIR), X-ray diffraction (XRD), field-emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDS) and thermogravimetric

analysis (TGA). Photocatalytic degradation was carried out by staining cotton fabrics with methylene blue (MB) solution, followed by exposure to simulated sunlight. The time-resolved color difference was tracked using a digital camera. Three consecutive photocatalytic degradations were carried out, to investigate the durability of the self-cleaning performance. Wash fastness were also investigated to evaluate the laundering durability. The ultraviolet protection factor (UPF) was measured to evaluate the anti-UV properties of the coated fabrics, because ZnO NPs strongly absorb UV wavelengths.

Experimental

Materials

Cotton fabrics were obtained from the Faculty of Textile Science and Technology, Shinshu University (Japan), with a warp/weft weave density of 88/56 inch⁻¹. Pretreatment was carried out to remove grease, wax and other chemical residues from the cotton fabric. The pretreatment process (Zhu and Takatera 2013, 2014) involved twice immersing the fabric in an 80 ± 2 °C water bath for 60 min. After air-drying at constant conditions of 20 ± 1 °C and 65 ± 5% relative humidity, 1 g of fabric was pretreated by immersing in a 100 ml nonionic detergent solution (polyoxyethylene lauryl ether, Kao Corporation Emulgen 108) with an Emulgen 108/deionized water ratio of 0.01 g/100 g, at 80 ± 2 °C for 60 min. The pretreated fabric was then rinsed thoroughly with deionized water. The fabric was then dried in air for 24 h under constant conditions.

ZnO NP aqueous solution was purchased for Sigma-Aldrich Corporation (USA), with a dispersion concentration of 50.1 wt%. All particles were smaller than 100 nm, and the average particle size was approximately 35 nm (The characterization data is evaluated and given in SI). In this study, ZnO NP aqueous solutions with weight ratios of 3, 5, 7, and 9% were prepared by dilution. MB powder was purchased from Sigma-Aldrich Corporation (USA). 1 g of MB powder in 6 L of H₂O was used as a model test contaminant.

Preparation of ZnO NP-coated fabrics

ZnO NPs can be coated on cotton fabrics by various techniques, such as dip-pad-cure, dip-coating, and

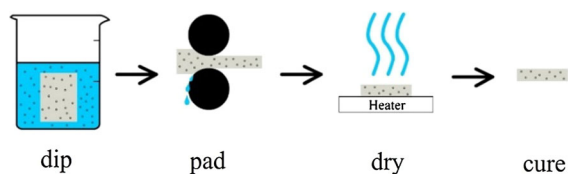
spraying processes (Wang et al. 2010). To maintain consistency with existing textile finishing equipment, dip-pad-dry-cure finishing was used to coat ZnO NP solution on the surface of cotton fabric, as shown in Scheme 1. Pretreated fabrics were dipped in prepared ZnO NP aqueous solutions with concentrations of 0, 3, 5, 7, or 9 wt% for 30 s, then padded with a picking-up ratio (*P*) of 108%, dried at 100 °C for 30 min, and finally cured at 130 °C for 2 min in a curing oven (Asone Corporation, Japan, OFW-450B). Curing assured good adhesion of the ZnO NPs to the substrate surface. The ZnO content of the coated cotton fabrics (*W*_{ZnO}) was calculated as follows:

$$W_{\text{ZnO}} = P \times \text{wt}\% \quad (1)$$

where *P* is the picking-up ratio, and wt% is the weight ratio of ZnO NP aqueous solution. The theoretical ZnO contents of cotton fabrics treated with 0, 3, 5, 7, and 9 wt% ZnO NP solutions were 0, 3.2, 5.4, 7.6, and 9.7%, respectively.

Characterization of ZnO NP-coated fabrics

FTIR spectra of uncoated and coated cotton fabrics were recorded using an IRPrestige-21 spectrometer (Shimadzu, Japan). The crystal structures of uncoated and ZnO NP-coated fabrics were characterized using a Rotorflex RU-200B apparatus (Rigaku, Japan), with a X-ray source of Ni-filtered Cu *K*_α radiation (λ = 0.15418 nm) and an operating voltage and current of 40 kV and 150 mA, respectively. The range of diffraction angles (2θ) was 2°–80°, with a step size of 0.1°. FESEM (S-5000, Hitachi, Japan) was used to investigate the morphology of the ZnO NP-treated cotton fabrics. Energy dispersive X-ray spectroscopy (EDS, JSM-6010LA, JEOL, Japan) was used to analysis the element of coated fabric. Decomposition of the cotton fabrics was investigated by thermogravimetric analysis (TGA), using a thermos plus TG8120 system (Rigaku, Japan). The change in the relative mass verses temperature was evaluated at a heating



Scheme 1 Coating procedure

rate of 10 °C/min with an air flush rate of 15 mL/min from ambient temperature to 600 °C.

Evaluation of self-cleaning properties of ZnO NP-coated fabrics

First, 10 µL of MB solution was used as a model test contaminant, by spraying on 2 × 2 cm cotton samples. Stained samples were then irradiated using a solar simulator (XES-40S3, SAN-EI ELECTRIC, Japan), with a wavelength range of 350–1100 nm and intensity of 1000 W/m². Photographic images were recorded of stained fabrics before, and after 6, 12, and 24 h of irradiation. This process constituted one photodegradation reaction cycle.

To investigate the durability of the coated fabrics to the photocatalytic degradation, further photodegradation cycles were carried out on the same fabric samples, again using MB solution as the contaminant. Consecutive staining was applied to the same area of the fabric sample. Photographic images were again recorded and analyzed.

Wash fastness of ZnO NP-coated fabrics

The wash fastness of coated cotton fabrics was carried out with a commercial washing machine (Mahltig et al. 2007) according to JIS L 1930. Each washing cycle was continued for 15 min at 40 °C. Samples can be obtained after 6 and 10 washing cycles. After washing, cotton fabrics were dried at room temperature and the self-cleaning property was evaluated.

Ultraviolet protection of the ZnO NP-coated fabrics

The UPFs of the ZnO NP-coated fabrics were evaluated using a UV-1000F ultraviolet transmission analyzer (Labsphere, USA), using EN13758-1:2001 standard. Each sample was tested four times at different positions, from which the average UPF was determined.

Results and discussion

Characterization of ZnO NP-coated cotton fabrics

The characterizations of ZnO NP-coated fabrics were evaluated by the TGA, the FTIR, XRD, FESEM and

EDS for the content, chemical structure, crystal structure and surface morphology and element analyzing respectively.

The ZnO content of coated fabrics could be controlled by adjusting the ZnO concentration of the colloidal solution, and pick up conditions, during the impregnation and pad stages, respectively. TGA was used to determine the ZnO content of the coated fabrics, and thus to determine the reliability of the coating treatment. TGA profiles of uncoated and 5 wt% ZnO NP-coated cotton fabrics are shown in Fig. 1. The curve of the uncoated fabric (black) indicated that pyrolysis proceeded in three stages, via the initial, main, and char decomposition steps (Zhu et al. 2004). In the initial stage (<150 °C), the cellulosic sample lost 1.4% in weight as absorbed moisture. Its chemical structure remained stable up to 300 °C, and any damage occurred mainly in the amorphous region. Pyrolysis in the crystalline region occurred at 300–370 °C. During this main stage, heat flow reached a maximum, and approximately 80% of the sample weight was rapidly lost. Char pyrolysis occurred at temperatures > 370 °C. The sample continued to dehydrate and decarboxylate until only 2.2% of the initial sample weight remained, releasing more water and carbon dioxide and producing alkene, carboxyl, and carbonyl products. The cotton fabric treated with 5 wt% ZnO solution (green) exhibited similar thermal behavior. The coated cotton fabric residual ash content was 7.7%, of which 5.5% constituted ZnO NPs. This was consistent with the theoretical ZnO content of 5.4%, as calculated by Eq. (1). Therefore, the calculated ZnO content was

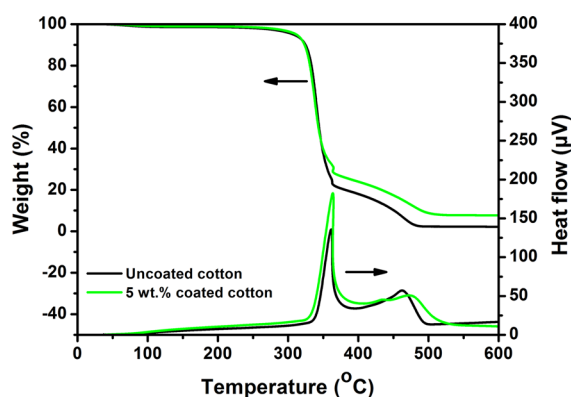


Fig. 1 TGA curves of uncoated and 5 wt% ZnO-coated cotton fabrics

consistent with the actual content, so could be used to estimate the ZnO content. Similar results were obtained for fabrics coated with differing wt% of ZnO NPs.

FTIR spectroscopy was used to examine the chemical structure of uncoated and ZnO-coated cotton samples, and thus any chemical changes occurring during coating. FTIR spectra of uncoated and 9 wt% ZnO NP-coated cotton fabrics are shown in Fig. 2. The FTIR spectrum of the uncoated cotton fabric exhibited the characteristic peaks of cotton cellulose, as shown in Fig. 2a. The broad absorption band at 3150–3500 cm^{-1} was assigned to the O–H stretching vibration of cotton cellulose. The absorption at 2900 cm^{-1} was attributed to the C–H stretching vibration. FTIR absorption bands characteristic of C–H, O–H, C–O, and C–O–C vibrations were observed at 1500–900 cm^{-1} . Absorption bands around 897 and 1159 cm^{-1} corresponded to C–O–C stretching vibrations of the β -d-glucoside linkage (Wei et al. 2012). The FTIR spectrum of the fabric changed little after coating with the ZnO NPs. This indicates no chemical reactions happened between ZnO and cotton cellulose.

The attachment of the ZnO NPs to the cotton fabric was also evidenced by XRD, as shown in Fig. 3. The XRD pattern of the uncoated cotton fabric in Fig. 3a shows two satellite peaks at 14.9° and 16.6°, and another more intense peak at 22.8°. These were characteristic of the crystal structure of cotton cellulose (Moafi et al. 2011). The satellite peaks at 14.9° and 16.6° were related to the amorphous phase of

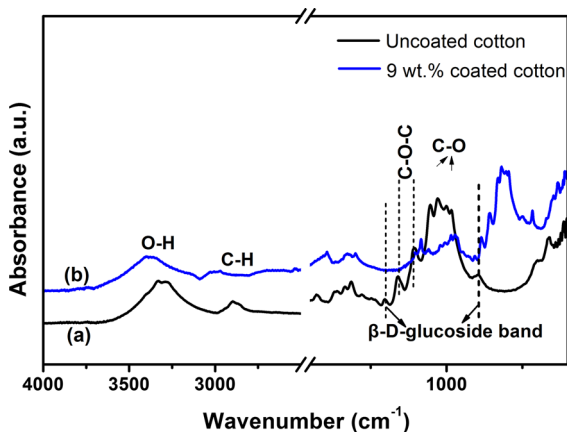


Fig. 2 FTIR spectra of uncoated and 9 wt% ZnO NP-coated cotton fabrics

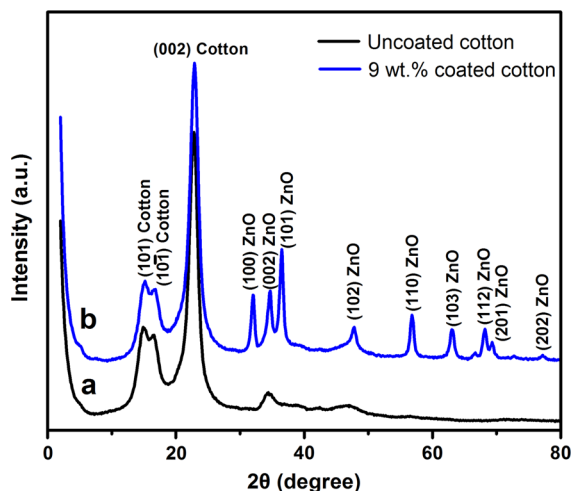


Fig. 3 XRD pattern of uncoated and 9 wt% ZnO-coated cotton fabrics

cotton fiber, and the peak at 22.8° to the crystalline phase. The positions and intensities of these three peaks in the XRD pattern of the ZnO-coated cotton fabric were also consistent with those of cotton cellulose. This indicated that coating did not affect the cotton crystal structure (Shateri Khalil-Abad et al. 2009). Nine additional diffraction peaks were observed in the pattern of the ZnO-coated cotton fabric in Fig. 3b, at 2θ of 32.0°, 34.7°, 36.5°, 47.8°, 56.8°, 63.0°, 68.2°, 69.3° and 77.2°. These corresponded to the (100), (002), (101), (102), (110), (103), (112), (201), and (202) planes of hexagonal wurtzite ZnO (Fateh et al. 2014), respectively.

Moreover, uniformly coating ZnO NPs on the surface of cotton fibers is of interest for self-cleaning textiles. The surface morphology of uncoated and 9 wt% ZnO NP-coated fabrics was observed by FESEM shown in Fig. 4. Meanwhile, the EDS analysis of 9 wt% ZnO NP-coated fabrics is shown in Fig. 5. Figure 4a, b show that the morphology of the uncoated cotton fiber appeared as dense tilted lines. These formed spiral fibrils with a twisted ribbon-like structure. Their surface was smooth and clean at the nanoscale. The clean surface indicated that pretreatment removed surface impurities, which was important for the subsequent coating process. The tilted lines on the surface of the ZnO NP-coated fibers were less apparent at the micron scale, as shown in Fig. 4c. Grooves between fibrils were densely filled with ZnO NPs, as shown in Fig. 4d. Compared with the rough surface of the uncoated fibers in Fig. 4b, the ZnO NP-

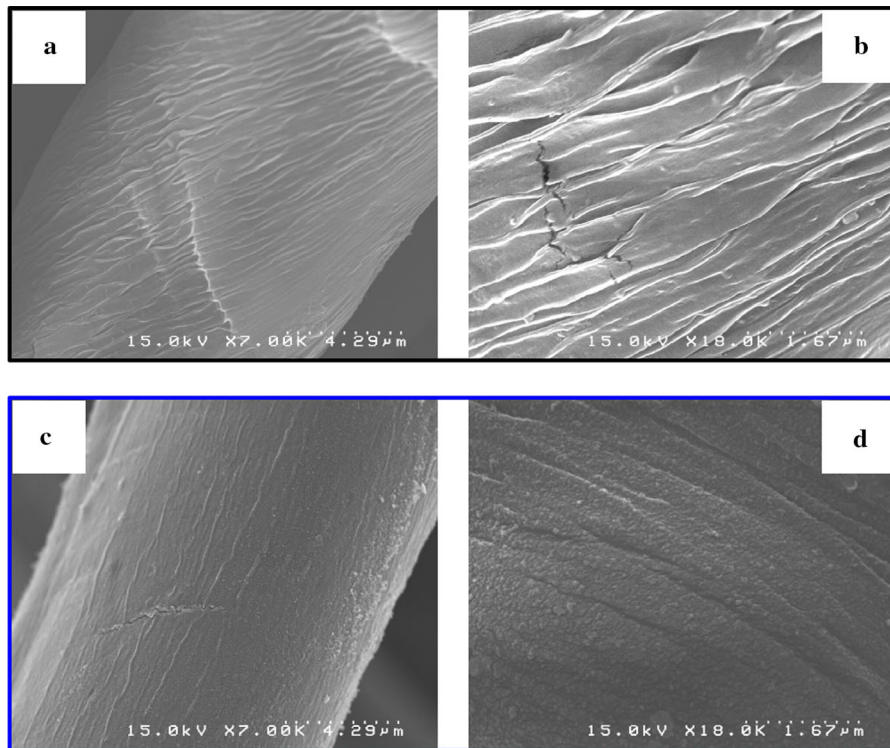


Fig. 4 SEM images of **a, b** uncoated and **c, d** 9 wt% ZnO NP-coated cotton fibers. Images were recorded at magnifications of **a–c** $\times 7000$, and **b–d** $\times 18,000$

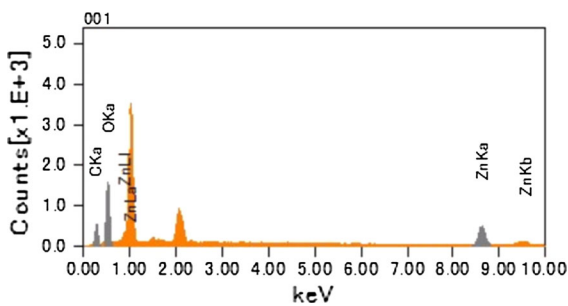


Fig. 5 EDS spectra of ZnO NPs coated cotton fabric

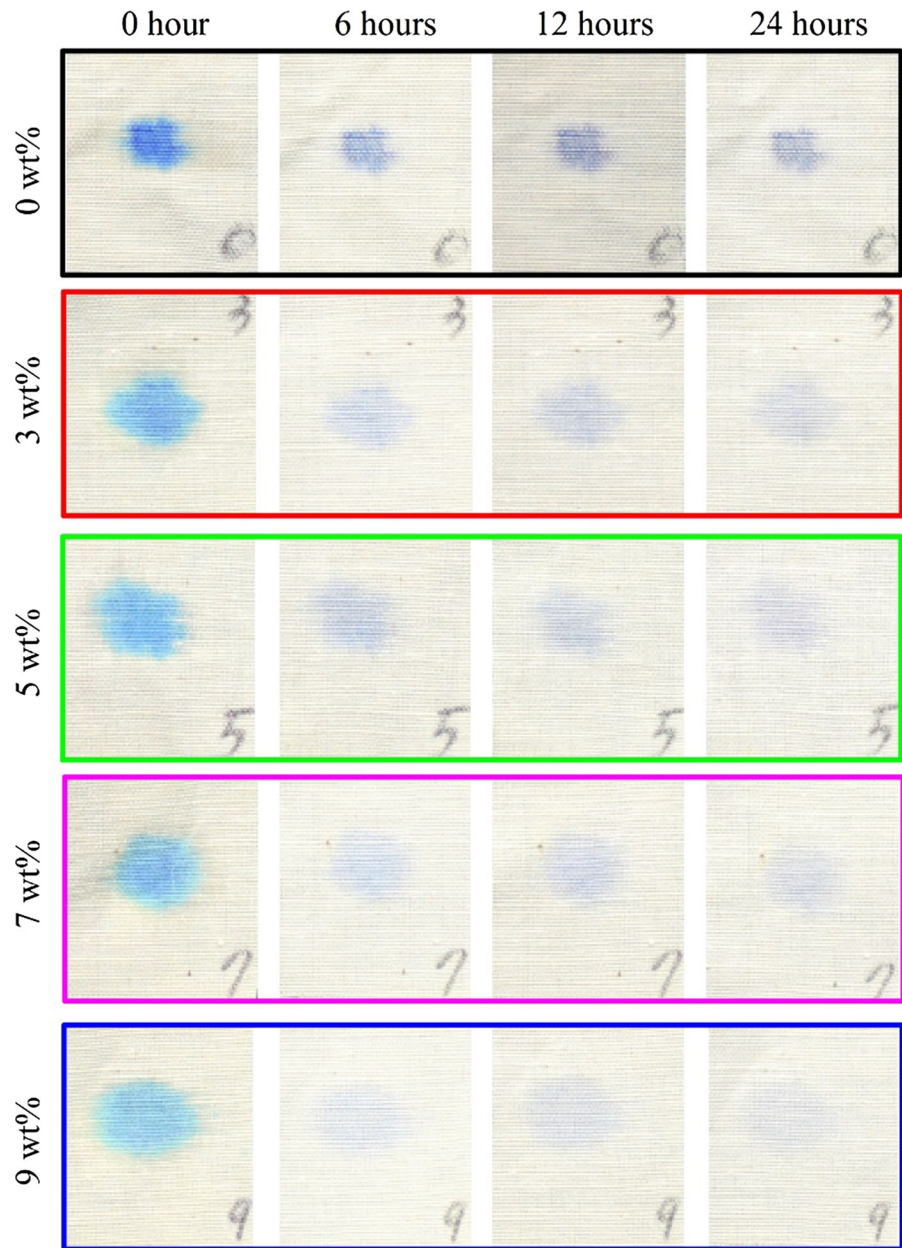
coated fibers appeared smoother. The ZnO coating was continuous and relatively homogeneous, indicating uniform coating. From Fig. 5, it has been demonstrated that elemental C, O and Zn can be found in the coated fabric, with the results coincided with the SEM images.

Self-cleaning properties

The removal of MB stains was used to evaluate the self-cleaning properties of the coated cotton fabrics.

The photocatalytic activity of the ZnO NP-coated cotton fabrics was studied by their photodegradation of MB dye. MB strongly adsorbs to many surfaces, exhibits good photo-resistance, and has a well-defined optical absorption band in the visible region (Moafi et al. 2011). Figure 6 shows photographic images of MB stains before, and after 6, 12, and 24 h of irradiation. The intensities of the MB stains on the ZnO NP-coated fabrics significantly decreased, because of photocatalytic degradation by the ZnO coating on the fabric surface. The MB stains remained clearly visible on the surface of the uncoated fabric. The photocatalytic degradation properties clearly depended on the ZnO NP content of the coated fabric. The rate of photocatalytic degradation increased with increasing ZnO NP content from 3 to 9 wt%. The blue MB stain had largely disappeared from the 9 wt% ZnO NP-coated cotton fabric after 6 h of irradiation. The 3 wt% ZnO NP-coated cotton fabric required 24 h to achieve a similar result. The diffusion of the MB dye was greater on the ZnO NP-coated fabrics, compared with the uncoated fabric. This indicated the greater hydrophilicity of the ZnO NP-coated fabrics.

Fig. 6 Degradation of MB stains by uncoated and various wt% ZnO NP-coated cotton fabrics



This self-cleaning phenomenon can be explained by the photocatalysis mechanism of metal oxide semiconductors (Carp et al. 2004; Chen et al. 2010; Fujishima 1972; Fujishima et al. 2000; Lee et al. 2015; Moore et al. 2014). As photocatalytic reactions initiated when the ZnO particles absorb photons from UV, under the absorption of light, the electrons in the valence band of ZnO are promoted to the conduction band, producing a positive hole in the valence band.

The photogenerated holes and electrons can induce oxidation–reduction reaction, which is able to form the hydroxyl radicals and reactive oxygen species. They are directly responsible for the oxidative degradation of organic compounds. The first reaction is the oxidation of water by a hole (h^+) to produce hydrogen ions (H^+) and a hydroxyl radical (O^*). Another reaction involves the reduction of molecular oxygen into a superoxide radical ($O_2^{\cdot-}$) by the electron (e^-).

The superoxide radical can be further reduced by another electron and then paired with two H^+ ions to form hydrogen peroxide (H_2O_2). The hydrogen peroxide can then be reduced by an electron to form hydroxyl radicals. Therefore, based on these reactions, both the electrons and the holes can produce hydroxyl and superoxide radicals that can subsequently degrade organic compounds. Thus, increasing the ZnO NP content resulted in more electron–hole being produced to catalyze the oxidative degradation of adsorbed MB. Therefore, the MB stains were removed more quickly by fabrics with higher ZnO NP contents. Unfortunately, UV light only accounts for less than 5% of the solar energy, while visible light accounts for about 50% of solar energy. Thus, another considerable reason for MB removal can be explained by the visible light activity of ZnO coated cotton which was ascribed to the photosensitization effect of MB (Chen et al. 2010). The MB can absorb visible light to be excited and the excited MB can inject electrons into the conduction band of the ZnO, forming conduction band electrons and the oxidized molecules to realize the charge separation. The radical reactions following the charge separation can result in the redox degradation of the pollutants. In this process, the process extended the photosensitization of ZnO from the UV to the visible region. Therefore it may accelerate the degradation of contaminant.

The durability of the photocatalytic degradation of the ZnO NP-coated fabrics was investigated by repeatedly staining the fabric with MB at the same position, followed by photocatalytic degradation. Results for the second and third consecutive photocatalytic degradations by the 9 wt% ZnO NP-coated fabric are shown in Fig. 7. For the second degradation, the characteristic blue color of MB had largely disappeared after 24 h, indicating good self-cleaning properties. After the third degradation, the MB stain appeared slightly darker. This was attributed to poorer contact between the MB and ZnO NPs because of the increased surface coverage by the degradation products. Some discoloration was still observed after 24 h for the third consecutive degradation, demonstrating the fabrics self-cleaning properties. Higher wt% ZnO NP-coated fabrics exhibited self-cleaning properties with greater longevity than those of lower wt% ZnO NP-coated fabrics. It is therefore preferable to coat textiles and clothes with a higher wt% of ZnO NPs,

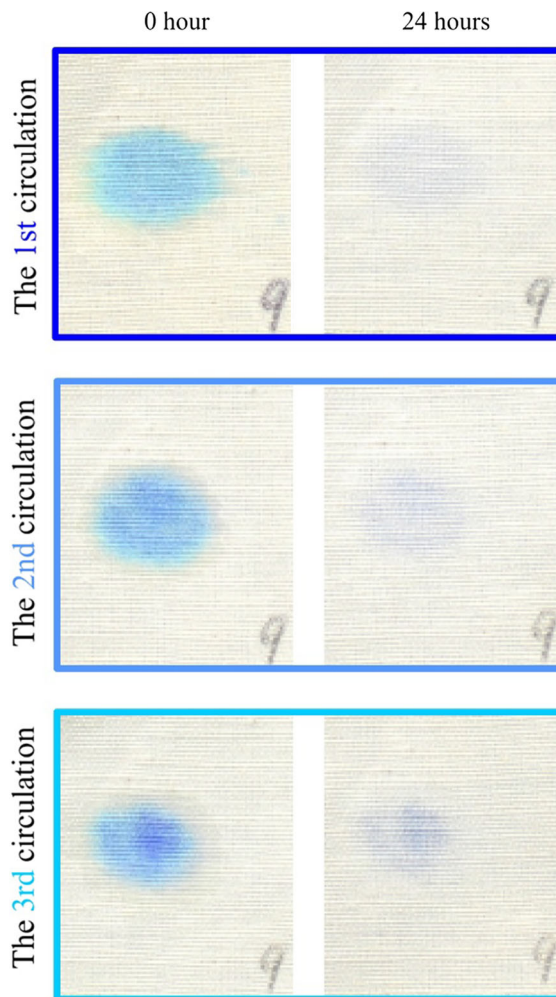


Fig. 7 Degradation of MB stains by the second and third consecutive degradations, demonstrating the durability of the ZnO NP-coated fabric

especially frequently soiled regions or garments that are not readily water washable.

Wash fastness

The wash fastness was carried out to evaluate the laundry durability of self-cleaning property of coated cotton fabrics after 6 and 10 washing times. Figure 8 shows degradation results on unwashed, 6 and 10 times washing of 9 wt% ZnO NP-coated fabrics before and after 24 h of light irradiation using a solar simulator. It can be seen that all washed fabrics showed the removal of MB solution under light irradiation. Moreover, the photodegradation of 6 times

washes was more significant than 10 times washes, and it had removed the MB solution as clean as unwashed fabric. It demonstrated that even if after several times washes, ZnO NPs were still coated on cotton fibers, which showed self-cleaning performance. On the other hand, after 10 times washes, the decoloration was decreased, implying that the wash fastness of coated cotton fabrics is necessary to be improved in the future.

UV transmission

ZnO NPs strongly absorb in the UV region, so the coated fabrics were expected to exhibit UV shielding properties. The UPF is defined as the ratio of the average effective UV irradiance of unprotected skin compared with that of skin protected by fabric. Thus, the UPF represents the UV shielding properties of the fabric. The UV blocking activities of the fabrics were evaluated by measuring the UPF, as shown in Fig. 9. The black spectrum in Fig. 8 shows that the uncoated fabric had a high UV transmission, with a UPF of 16.41. Thus, the cotton cellulose exhibited poor UV shielding properties. All ZnO NP-coated cotton

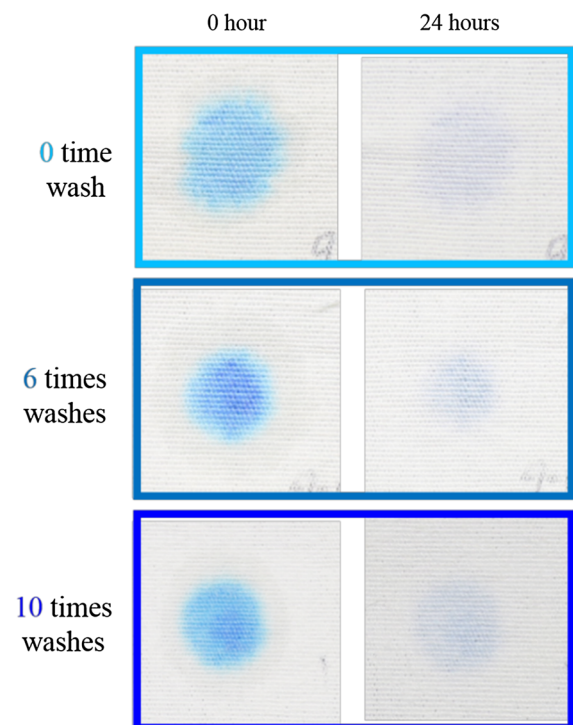


Fig. 8 Wash fastness of ZnO NPs coated cotton fabrics, showing different wash times

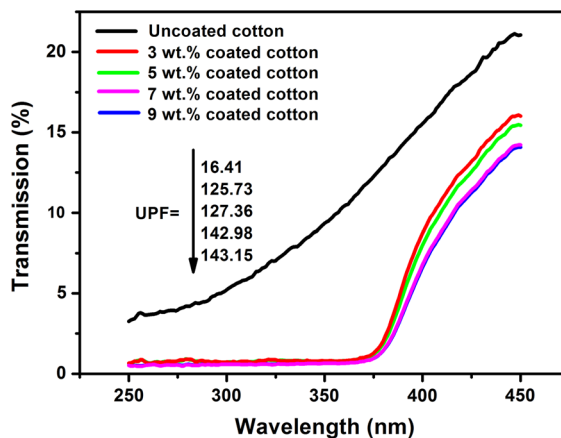


Fig. 9 UV transmission spectra of uncoated and coated cotton fabrics

fabrics exhibited nearly 0% UV transmission, while transmission in the visible region showed no significant decline. Absorption by the ZnO NPs was clearly responsible for the different transmissions in the UV and visible regions.

All UPF values of the ZnO NP-coated fabrics were >100, representing >99.99% UV absorption by the ZnO NP coating, and thus excellent UV blocking. The UV blocking properties of the coated fabrics also depended on ZnO content. Increasing the ZnO NP content from 3 to 9 wt% increased the UPF from 125.73 to 143.15. An UPF of >50 is generally considered to indicate excellent UV blocking, so the prepared fabrics exceeded the typical UV protection requirements.

Conclusions

ZnO NP-coated cotton fabrics were fabricated via a dip-pad-dry-cure coating process, using different weight ratios of ZnO NP solutions. The ZnO NPs exhibited an absorption band at 250–360 nm, a uniform particle size of approximately 36 nm, good water stability, and a high positive zeta potential. TEM images showed lattice fringes of [100] planes, with a lattice spacing of 0.28 nm. The ZnO contents of the coated cotton fabrics obtained by TGA agreed well with calculated values, demonstrating the feasibility of the dip-pad-dry-cure coating method. FTIR spectroscopy, XRD, and FESEM showed that the ZnO NPs were uniformly coated on the cotton fiber surface.

Self-cleaning tests showed that the coated cotton fabrics exhibited good photocatalytic activity against MB, with increased photodegradation of MB observed with increasing irradiation time. The self-cleaning fabric exhibited good durability during three consecutive photocatalytic degradation reactions, although some loss in activity was observed. Results of wash fastness also showed color removal after 10 times washing under light irradiation. The ZnO NP-coated fabrics exhibited excellent UV blocking properties, with UPF values dependent on ZnO content. The UPF was >125 when the ZnO content of the coated fabric was >3.2%. The ZnO NP-coated cotton fabrics are therefore suitable for self-cleaning and anti-UV applications. These findings provide a potential model for the practical application of self-cleaning textiles.

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