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Antimicrobial and Self-Cleaning Finishing of Cotton Fabric Using Titanium Dioxide Nanoparticles

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Abstract

Due to its photocatalytic properties, titanium dioxide (TiO2) has been regarded as an appealing antibacterial component. It is also chemically stable, non-toxic, affordable, and generally accepted as a safe (GRAS) material. Titanium dioxide nanoparticles considerably enhanced these qualities (TiO2NPs). In order to better protect sick children from microbial and bacterial infection in children's hospitals, TiO2NPs are utilised to increase the antibacterial, self-cleaning, and UV characteristics on cotton textiles. All necessary measures are looked at and included into our work.

Keywords Titanium dioxide, nanoparticles, cotton fabric, antimicrobial activity, self-cleaning property

Introduction

High-performance fabrics have been created in recent years using many nanoparticle types, each with its own special qualities. [1] Due to their distinct physiochemical characteristics in biological applications, metal oxide nanoparticles including zinc oxide (ZnO), magnesium oxide (MgO), titanium dioxide (TiO2), and iron oxide (Fe2O3) have found significant application. [2-7] The intriguing qualities of titanium dioxide nanoparticles, such as their optical, catalytic, long-term stability, and non-toxicity, set them apart from the others. [8-14] Also, its usages in textile finishing produce self-cleaning [15, 16], antimicrobial, [17, 18] ultraviolet (UV) protection [19, 20], mothproofing [21], and flame retardancy properties. [22]

The morphology, size, chemistry, source, and nanostructure of nanoparticles as well as other intrinsic characteristics such as their size and shape have a significant impact on their antibacterial activity. [23-26]

In particular, the photocatalytic performance of TiO2NPs, which is highly reliant on its morphological, structural, and textural features, considerably influences the antibacterial activity of TiO2NPs.. [27] Several TiO2NPs have been created using various synthesis techniques. According to studies on synthesis, factors like hydrothermal temperatures, the initial acid content, etc., have an impact on the shape and crystalline structure of TiO2NPs.[28] The most significant factors influencing TiO2NPs' physicochemical characteristics, and therefore their antibacterial capabilities, are both their crystal structures and their shapes. [29] Anatase exhibits the greatest photocatalytic and antibacterial activity among crystal formations. Several studies have demonstrated that an anatase structure may catalyse a photocatalytic process to create OH radicals.

In this paper, the finishing of cotton fabric is investigated using TiO_2NPs by spraying method. This treatment gave high values of antimicrobial, and ultraviolet protection in addition to self-cleaning

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properties. All the required measurements are investigated.

Materials, Methods, and Measurements

Materials

Cotton fabric (100%) was kindly obtained from El-Mahalla Company for Spinning and Weaving, El-Mahalla, Egypt.

TiO_2 NPs (of particle size 700 nm) were purchased from Sigma-Aldrich, Egypt.

Acrytex-330 (used as a binder additive) was kindly supplied by Dystar company, Egypt.

Methods

The following recipe was used to treat cotton fabric:

- 10 ml of Acrytex-330 binder (const)
- (1, 2, 3 %) of TiO2 NPs of fabric weight
- W.O.S = 3 gm of cotton fabric
- 40 ml of water (const)

The cotton sample was sprayed with the finishing solution containing the previous ingredients

The sample was left to dry at room temperature and then fixed at 150° C for 5 minutes.

Measurements

Antimicrobial Test

The disc agar diffusion technique was used to investigate the antibacterial activity. Staphylococcus aureus ATCC 6538-P (G+ve), Escherichia coli ATCC 25933 (G-ve), Candida albicans ATCC 10231 (yeast), and Aspergillus niger NRRL-A326 were the four typical 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. Potato dextrose agar plates seeded by 0.1 ml (10^6 cells/ml) of the fungal inoculum were used to evaluate the antifungal activities. Textile-treated discs (15mm diameter) were placed over the inoculated plates. 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 millimeter-sized zone of inhibition was used to measure the test agent's antibacterial activity (mm). The experiment was run many times, and the mean value was noted.

Scanning Electron Microscopic (SEM) Test:

Using Quanta FEG250, field-emission scanning electron microscopy (FE-SEM) was used to examine the morphological characteristics of the pre- and post-treated textiles (Thermo Fisher Scientific, Brno, Czech Republic). Applying a work distance of 21 mm and an acceleration voltage of 20 kV allowed this to examine the chemical composition of the pre- and post-treated textiles using energy-dispersive X-ray spectroscopy (TEAM-EDX Model).

Ultraviolet Protection Test

The UVPF (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. [30, 31]

Self-Cleaning Activity Test

By monitoring the progression of methylene blue's degradation, the photocatalytic activity of cotton textiles that had 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. A fluorescent lamp (TC-L18W, AC230V-50 Hz, China) was used to provide visible light illumination at a distance of 5 cm and a light intensity of 44 W cm2). To achieve an equilibrium between photocatalysis and methylene blue under ambient circumstances, a cotton sample of 1 g was agitated for 30 minutes in 50 ml of an aqueous solution of methylene blue (10 mg/L at pH 6.5). After then, the sample was irradiated with visible light. 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 A0 is the initial absorption and it is the variable absorption at various irradiation intervals, C0 is the starting concentration of methylene blue, Ct is the concentration at different irradiation periods, and

Results and Discussion:

The samples were chosen to be tested with the precisely mentioned finishing solution using (2% conc.) of (TiO_2NPs) of fabric (cotton) weight.

Antimicrobial Test

Due to its photocatalytic properties, chemical stability, non-toxicity, low cost, and status as a generally recognised as safe (GRAS) material, titanium dioxide (TiO2) has been regarded as an appealing antibacterial molecule.

The following table demonstrates the results of this test. The table shows that the treated cotton fabric containing (TiO2NPs) has antibacterial action against a variety of test microorganisms, including yeast (C. Albicans), fungus, G+ve bacteria (S. aureus), and G-ve bacteria (E. coli) (A. niger).

Metal oxide exhibits outstanding antifungal and antibacterial capabilities against a wide variety of both Gram-positive and Gram-negative bacteria, according to several studies.

Scanning Electron Microscopic (SEM)

Figure 1 The following figure represents the micrograph obtained on treating cotton samples using TiO_2NPs.

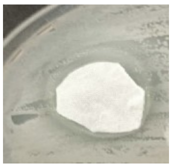
Ultraviolet Protection

Three cotton samples are treated using different TiO_2NPs concentrations which are 1, 2, and 3% (TiO2NPs), the Ultraviolet factor obtained are 112, 125, and 172, respectively. Increasing the values proved more efficient.

Self-Cleaning Test

Three cotton samples were prepared for Self-Cleaning Test using three different concentrations 1, 2, and 3% (TiO_2 NPs) of fabric weight. The results obtained are 118,129, and 156 for each concentration 1,2,3, respectively. Increasing the values proved more efficient.

Table1. antimicrobial results obtained by cotton fabric (Aspergillus niger – Candida albicans- Staphylococcus aureus- Escherichia coli).

Clear zone (ϕmm)			
Staphylococcus aureus	**escherichia coli**	**Candida albicans**	**Aspergillus niger**
17 	**0** 	21 	29 

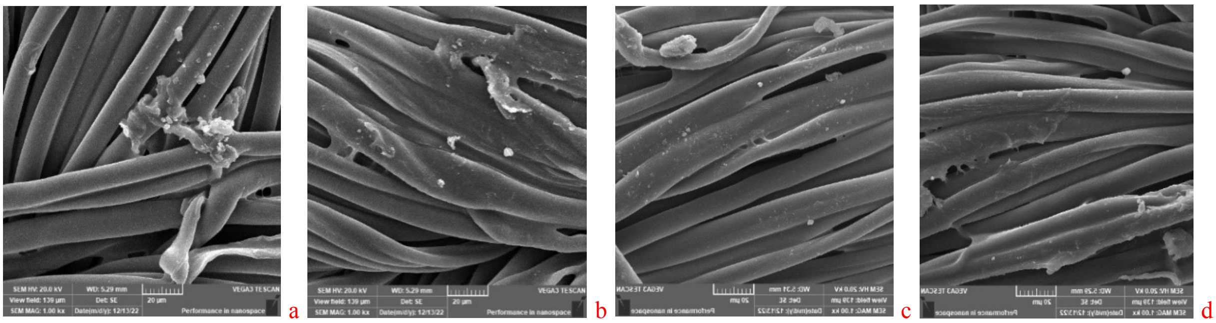


Figure 1: SEM images for (a) and (b) are the untreated samples, (c) and (d) are the treated samples with 2%(of fabric weight) conc. of (TiO2NPs).

Table 2 the weight percentage and atomic percentage of two different cotton fabric areas.

Samples	C		O		Al		Sr		Eu	
	Wt.%	At.%	Wt.%	At.%	Wt.%	At.%	Wt.%	At.%	Wt.%	At.%
Region 1	59.05	67.11	38.47	32.43	0.86	0.46	1.31	0.02	0.03	0.01
Region 2	58.84	66.89	38.51	32.36	1.03	0.52	1.24	0.19	0.17	0.02

Conclusion

In this work, the spraying approach is effectively employed to apply titanium dioxide nanoparticles to cotton textiles. and applied to cotton textiles as a functional treatment while Acrytex-330 (used as a binder) acts as a cross-linking agent. Some characteristics of cotton textiles, such as self-cleaning, antimicrobial, and UV blocking, are enhanced by the addition of titanium dioxide nanoparticles.

Additionally, the sample that has been treated with nanoparticles performs well.

It is anticipated that titanium dioxide nanoparticles would be employed to create smart textiles and high-performance fabrics.

Conflict of Interest

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

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References

1. Derakhshan, S.J., Karimi, L., Zohoori, S., Davodiroknabadi, A. and Lessani, L., "Antibacterial and Self-Cleaning Properties of Cotton Fabric Treated with Tio 2/Pt". *Indian Journal of Fibre & Textile Research (IJFTR)*, **43**(3) 344-351 (2018)
2. Mohamed, A.L. and Hassabo, A.G., "Composite Material Based on Pullulan/Silane/Zno-Nps as Ph, Thermo-Sensitive and Antibacterial Agent for Cellulosic Fabrics". *Advances in Natural Sciences: Nanoscience and Nanotechnology*, **9**(4) 045005 (1-9) (2018)
3. Ibrahim, N.A., Nada, A.A., Hassabo, A.G., Eid, B.M., Noor El-Deen, A.M. and Abou-Zeid, N.Y., "Effect of Different Capping Agents on Physicochemical and Antimicrobial Properties of Zno Nanoparticles". *Chemical Papers*, **71**(7) 1365-1375 (2017)
4. El-Naggar, M.E., Hassabo, A.G., Mohamed, A.L. and Shaheen, T.I., "Surface Modification of Sio2 Coated Zno Nanoparticles for Multifunctional Cotton Fabrics". *Journal of Colloid and Interface Science*, **498** 413-422 (2017)
5. Hassabo, A.G. and Mohamed, A.L., "Novel Flame Retardant and Antibacterial Agent Containing Mgo Nps, Phosphorus, Nitrogen and Silicon Units for Functionalise Cotton Fabrics". *Biointerface Research in Applied Chemistry*, **9**(5) 4272 - 4278 (2019)
6. El-Zawahry, M.M., Hassabo, A.G., Abdelghaffar, F., Abdelghaffar, R.A. and Hakeim, O.A., "Preparation and Use of Aqueous Solutions Magnetic Chitosan / Nanocellulose Aerogels for the Sorption of Reactive Black 5". *Biointerface Research in Applied Chemistry*, **11**(4) 12380 - 12402 (2021)
7. Zayed, M., Othman, H., Ghazal, H. and Hassabo, A.G., "Psidium Guajava Leave Extract as Reducing Agent for Synthesis of Zinc Oxide Nanoparticles and Its Application to Impart Multifunctional Properties for Cellulosic Fabrics". *Biointerface Research in Applied Chemistry*, **11**(5) 13535 - 13556 (2021)
8. Chen, X. and Mao, S.S., "Titanium Dioxide Nanomaterials: Synthesis, Properties, Modifications, and Applications". *Chemical reviews*, **107**(7) 2891-2959 (2007)
9. Raliya, R., Biswas, P. and Tarafdar, J.C., "Tio2 Nanoparticle Biosynthesis and Its Physiological Effect on Mung Bean (Vigna Radiata L.)". *Biotechnology Reports*, **2** 22-26 (2015)
10. Ortelli, S., Costa, A. and Dondi, M., "Tio2 Nanosols Applied Directly on Textiles Using Different Purification Treatments". *Materials*, **8** 7988-7996 (2015)
11. Hebeish, A.A., Abd El-Hady, M.M. and Youssef, A.M., "Tio_2 Nanowire and Tio_2 Nanowire Doped Ag-Pvp Nanocomposite for Antimicrobial and Self-Cleaning Cotton Textile". *Carbohydrate Polymers*, **91**(2) 549-559 (2013)
12. Šuligoj, A., Štangar, U.L., Ristić, A., Mazaj, M., Verhovšek, D. and Tušar, N.N., "Tio2–Sio2 Films from Organic-Free Colloidal Tio2 Anatase Nanoparticles as Photocatalyst for Removal of Volatile Organic Compounds from Indoor Air". *Applied Catalysis B: Environmental*, **184** 119-131 (2016)
13. Liu, W., Zhang, H., Wang, H.-g., Zhang, M. and Guo, M., "Titanium Mesh Supported Tio2 Nanowire Arrays/Upconversion Luminescence Er3+-Yb3+ Codoped Tio2 Nanoparticles Novel Composites for Flexible Dye-Sensitized Solar Cells". *Applied Surface Science*, **422** 304-315 (2017)
14. Tanev, P.T., Chibwe, M. and Pinnavaia, T.J., "Titanium-Containing Mesoporous Molecular Sieves for Catalytic Oxidation of Aromatic Compounds". *Nature*, **368**(6469) 321-323 (1994)

15. Veronovski, N., Rudolf, A., Smole, M.S., Kreže, T. and Geršak, J., "Self-Cleaning and Handle Properties of Tio2-Modified Textiles". *Fibers and polymers*, **10**(4) 551-556 (2009)
16. Karimi, L., Mirjalili, M., Yazdanshenas, M.E. and Nazari, A., "Effect of Nano Tio2 on Self-Cleaning Property of Cross- Linking Cotton Fabric with Succinic Acid under Uv Irradiation". *Photochemistry and photobiology*, **86**(5) 1030-1037 (2010)
17. Montazer, M., Pakdel, E. and Behzadnia, A., "Novel Feature of Nano- Titanium Dioxide on Textiles: Antifelting and Antibacterial Wool". *Journal of Applied Polymer Science*, **121**(6) 3407-3413 (2011)
18. Khurana, N. and Adivarekar, R., "Effect of Dispersing Agents on Synthesis of Nano Titanium Oxide and Its Application for Antimicrobial Property". *Fibers and Polymers*, **14**(7) 1094-1100 (2013)
19. Uğur, Ş.S., Sarıšık, M. and Aktaş, A.H., "Nano-Tio2 Based Multilayer Film Deposition on Cotton Fabrics for Uv-Protection". *Fibers and polymers*, **12**(2) 190-196 (2011)
20. Khan, M.Z., Ashraf, M., Hussain, T., Rehman, A., Malik, M.M., Raza, Z.A., Nawab, Y. and Zia, Q., "In Situ Deposition of Tio2 Nanoparticles on Polyester Fabric and Study of Its Functional Properties". *Fibers and Polymers*, **16**(5) 1092-1097 (2015)
21. Nazari, A., Montazer, M. and Dehghani-Zahedani, M., "Nano Tio2 as a New Tool for Mothproofing of Wool: Protection of Wool against Anthrenus Verbasci". *Industrial & Engineering Chemistry Research*, **52**(3) 1365-1371 (2013)
22. Lessan, F., Montazer, M. and Moghadam, M., "A Novel Durable Flame-Retardant Cotton Fabric Using Sodium Hypophosphite, Nano Tio2 and Maleic Acid". *Thermochimica Acta*, **520**(1-2) 48-54 (2011)
23. De Oliveira, R.C., De Foggi, C.C., Teixeira, M.M., Da Silva, M.D.P., Assis, M., Francisco, E.M., Pimentel, B.N.A.d.S., Pereira, P.F.d.S., Vergani, C.E. and Machado, A.L., "Mechanism of Antibacterial Activity Via Morphology Change of A-Agvo3: Theoretical and Experimental Insights". *ACS applied materials & interfaces*, **9**(13) 11472-11481 (2017)
24. Pal, S., Tak, Y.K. and Song, J.M., "Does the Antibacterial Activity of Silver Nanoparticles Depend on the Shape of the Nanoparticle? A Study of the Gram-Negative Bacterium Escherichia Coli". *Applied and environmental microbiology*, **73**(6) 1712-1720 (2007)
25. Gilbertson, L.M., Albalghiti, E.M., Fishman, Z.S., Perreault, F., Corredor, C., Posner, J.D., Elimelech, M., Pfefferle, L.D. and Zimmerman, J.B., "Shape-Dependent Surface Reactivity and Antimicrobial Activity of Nano-Cupric Oxide". *Environmental science & technology*, **50**(7) 3975-3984 (2016)
26. López de Dicastillo, C., Patiño, C., Galotto, M.J., Palma, J.L., Alburquenque, D. and Escrig, J., "Novel Antimicrobial Titanium Dioxide Nanotubes Obtained through a Combination of Atomic Layer Deposition and Electrospinning Technologies". *Nanomaterials*, **8**(2) 128 (2018)
27. He, Z., Cai, Q., Fang, H., Situ, G., Qiu, J., Song, S. and Chen, J., "Photocatalytic Activity of Tio2 Containing Anatase Nanoparticles and Rutile Nanoflower Structure Consisting of Nanorods". *Journal of Environmental Sciences*, **25**(12) 2460-2468 (2013)
28. Sarkar, D., Ghosh, C.K. and Chattopadhyay, K.K., "Morphology Control of Rutile Tio 2 Hierarchical Architectures and Their Excellent Field Emission Properties". *CrystEngComm*, **14**(8) 2683-2690 (2012)
29. Burda, C., Chen, X., Narayanan, R. and El-Sayed, M.A., "Chemistry and Properties of Nanocrystals of Different Shapes". *Chemical reviews*, **105**(4) 1025-1102 (2005)
30. AATCC Test Method (183-2004), "Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics", in *Technical Manual Method* American Association of Textile Chemists and Colorists. 317-321 (2010)
31. Australian/New Zealand Standard AS/NZS 4399:1996, "Sun Protective Clothing—Evaluation and Classification", (1996)

التجهيز المقاوم للميكروبات والتنظيف الذاتي للأقمشة القطنية باستخدام جزيئات ثاني أكسيد التيتانيوم النانوية

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المستخلص: يعتبر ثاني أكسيد التيتانيوم (TiO2) مركبًا جذابًا مضادًا للميكروبات نظرًا لطبيعته التحفيزية الضوئية ، إلى جانب أنه مستقر كيميائيًا وغير سام وغير مكلف ومعترف به عمومًا على أنه مادة آمنة (GRAS). تم تحسين هذه الخصائص بشكل كبير بواسطة جزيئات ثاني أكسيد التيتانيوم النانوية (TiO2NPs). في هذا البحث ، تُستخدم TiO2NPs لتحسين خصائص مضادات الميكروبات والتنظيف الذاتي والأشعة فوق البنفسجية على الأقمشة القطنية لحماية الأطفال المرضى من العدوى الجرثومية والبكتيرية في مستشفيات الأطفال. يتم فحص جميع القياسات المطلوبة وإدراجها في عملنا..

الكلمات المفتاحية: ثاني أكسيد التيتانيوم ، الجسيمات النانوية ، الأقمشة القطنية ، النشاط المضاد للميكروبات ، خاصية التنظيف الذاتي