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UV–VISIBLE ANALYSIS OF TITANIUM DIOXIDE-BASED FUNCTIONAL TEXTILES: OPTICAL PROPERTIES AND SELF-CLEANING POTENTIAL

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Abstract

The absorbance data in UV–visible region of the samples doping of titanium dioxide with chitosan were analyzed with the aim of developing self-cleaning textiles based on titanium dioxide. This spectrum has 51 values spaced out 10 nm from 300 to 800 nm. All tabulated values are retained in comparison with no smoothing, normalization or removal of negative readings. The maximum tabulated values occur at 790 nm and are 0.117, 0.094r. The short-wavelength minima are −0.004, −0.005 and −0.005, respectively. The sudden increase from 780 to 790 nm needs to be confirmed before the long wavelength maximum can be attributed to a material transition. The measured comparison is read in conjunction with literature pertaining to optical geometry and dye photochemistry and textile coatings. The spectra define differences in reported optical response, but due to the limited record there is no definition of sample formulations or optical geometry/replicate variability. From these scans alone, the material-specific band gap, the photocatalytic activity and cleaning efficiency in the visible-light range can not be determined. There is still a need to perform controlled dye or stain measurements to relate the optical response to the self cleaning performance.

Keywords:
Titanium dioxide; self-cleaning textile; UV–visible spectroscopy; diffuse reflectance; dye discoloration; optical band gap; photocatalysis

Introduction

The use of a titanium dioxide coated textile as a self-cleaning material requires the change of the fate of a contaminant under defined illumination. One piece of evidence for that is a white oxide coating, or an ultraviolet absorption feature or fading dye stain. A convincing interpretation is achieved by measurements to separate the light absorption from removal of the contaminant. UV – visible spectroscopy has particular significance, because the optical response of the textile as well as the signal of a coloured probe, depending on concentration, in solution can be investigated. The analytical challenge is to determine the meaning of each measurement and to use it to describe the photocatalytic performance.

The semiconductor origin of the photochemistry of TiO2 was first shown by Fujishima and Honda by photoelectrochemical water splitting at the semiconductor electrode [1]. The same is true for a coating of a textile, where absorbed photons may create electronic excitations, which may undergo charge transfer at an exposed surface. The usefulness of this stain removal will depend upon how much and how often the coating comes in contact with the stain, the surrounding media, and the competing loss of the excited charge carriers. The experiment with the creation of the electrodes is a photochemical principle. It does not give an activity value for an independent preparation of the fabric.

Wetting can also change as a result of light. Wang and co-workers showed an important basis for understanding the spreading of water on the irradiated oxide coatings, with the creation of a light-induced amphiphilic titanium dioxide surface [2]. This behaviour can be helpful in cleaning but wetting and chemical conversion are different observables. Water spreading can spread a stain without destroying the chromophore. Chemical conversion, on the other hand, can alter colour but will not provide an obviously water-repellent surface. Therefore, an article on UV–visible analysis should be related to a well-defined chemical or colour-related end point, rather than assuming that all self-cleaning is the same process.

Because of the low temperature routes of coating, the relevance of titania to substrates, such as textiles, which are unsuitable for conventional ceramic processing became more important. Daoud and Xin reported on the sol–gel titania coatings and the formation of anatase crystallites on cotton under relatively low processing temperatures [3,4]. These studies set up practical precedents for placing photoactive oxide on cellulose. They also provide a reason for the inclusion of a coating procedure, optical spectrum, and a cleaning test in distinct phases of an investigation. A literature precedent can be a basis for exploring a novel formulation but the measured properties will be unique to the preparation.

Later, the self-cleaning cotton was fabricated via the dip-pad-dry-cure process by the same group of researchers, which also addressed the optical behavior and stain related performance of the self-cleaning cotton [5]. Maity, Tiwari and Vishnoi studied aqueous titanium dioxide coating on cotton and silk and separately evaluated the self cleaning and the ultraviolet protection [6]. The difference is important as a fabric may scatter and absorb the ultraviolet rays without necessarily getting rid of a stain very quickly. Lower transmitted intensity, therefore, is evidence, first of all, with regard to the optical shielding. It is related to cleaning which is the measurement of the reaction under a documented light source.

A second problem arises with the visible-light studies. Ahmad and Kan studied the dye-sensitized TiO2 on cotton and Ahmad, Kan and Yao studied the photoactive cotton containing a reactive dye and TiO2 [7,8]. The purpose of such systems is to intentionally include a visible-light absorber. This performance cannot be directly transferred to an unsensitized coating of titanium dioxide–polymer. If the coloured contaminant is the probe itself, it might also absorb the irradiation and be involved in a sensitization pathway. This possibility makes it difficult to use methylene blue to assess the visible-light photocatalytic activity, as was shown by Yan and co-workers [9].

There are also a number of potential chemical explanations for the loss of colour. Mills and Wang were able to demonstrate that such bleaching of methylene blue by TiO2 sensitisation in particular circumstances is not the result of oxidative destruction but that the dye was reduced to the colourless form [10]. The device of the finding has a direct applicability to the language of a textile article. The first description of a decreasing visible band should be either loss of chromophore or discoloration. There is a need for more evidence on products and carbon balance in order to make stronger statements on complete degradation. UV – visible spectroscopy is still a useful technique when the conclusion equals the actual amount measured.

In this article, a descriptive comparison of the absorbance spectra of the MK1, MK2 and MK 3 is provided along with the literature-based framework for the interpretation of self-cleaning textiles based on titanium dioxide. The spectral analysis shows the range measured, relative signals and tabulated maximums. The methodological discussion then covers the measurement of a scattering textile, the conversion of absorbance of the dye to concentration and the discrimination of controls that highlight photocatalysis from adsorption and direct photolysis. A comparison of the samples is presented in Section 3.6. Control conditions and kinetic equations are used to explain the necessary extra measurements to determine self-cleaning performance.

2 Materials and analytical approach

The preparation context is a functionalized fabric with titanium dioxide, where chitosan and polyethylene glycol are thought of as ingredients in a coating formulation. The basic idea is to add titanium dioxide to these polymers and to coat using a dip coating or pad dry cure operation [11]. The optical specimen is the final product (the fabric) and not a single powder evaluated alone. This separation is vital since all three – the polymer, the textile structure and the deposited oxide – have the potential to impact the light that reaches the detector.

In optical interpretation the coating bath is regarded as a dispersion of the particles of TiO2 in the liquid with a binder. When a bath is described as being homogeneous, molecular dissolution of the oxide is not determined. A uniform dispersion may also scatter light very highly and the apparent absorbance may vary with aggregation or sedimentation of the apparent dispersion. The description of the specimens for measuring a powder suspension, a dried coating and a finished textile thus needs to be different. Their spectra will not be comparable if they are not on a common absorbance scale with explanation of geometry and optical path differences.

Sample names should be used to refer to a documented preparation and not describe a property. The record of measurements does not specify to which of the available specimens the available measurements apply, other than identifying the specimens without correlating these markings with the loading of TiO2 and content of binder, and untreated fabric and a binder-only control. A full specimen record also would provide information on the type of textile, prewashing, formulation, mass of textile deposited per exposed area, and drying history. As such, discrepancies between the three curves reported are explained, but not attributed to an unconfirmed formulation change.

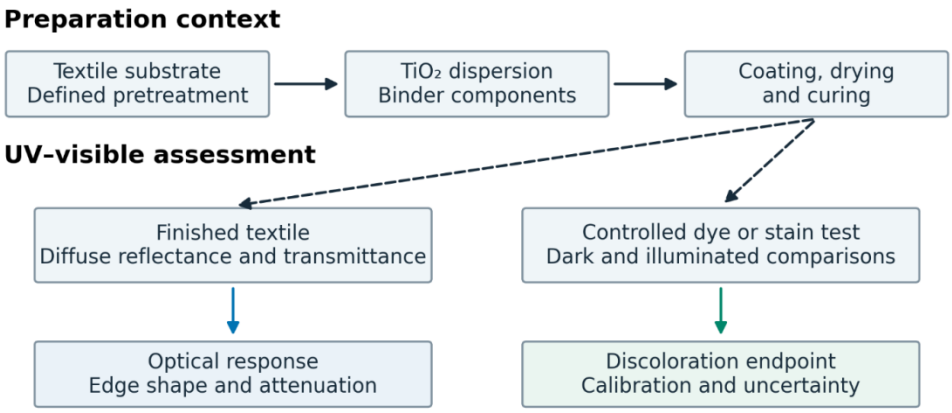


Figure 1. Preparation context and UV–visible assessment of a titanium-dioxide-functionalized textile. The coating context is informed by the thesis and textile-coating literature [11,5]. Dashed arrows lead to proposed analytical routes. The diagram does not represent a completed spectral or photocatalytic experiment.

UV–Visible optical response

The spectra from the three recordings are compared in the entire range 300–800 nm in figure 5. They have the differences ranging between 0.000 and 0.002 at each wavelength. This is a visual comparison of the scans available and is not statistically significant due to the lack of replicate variability.

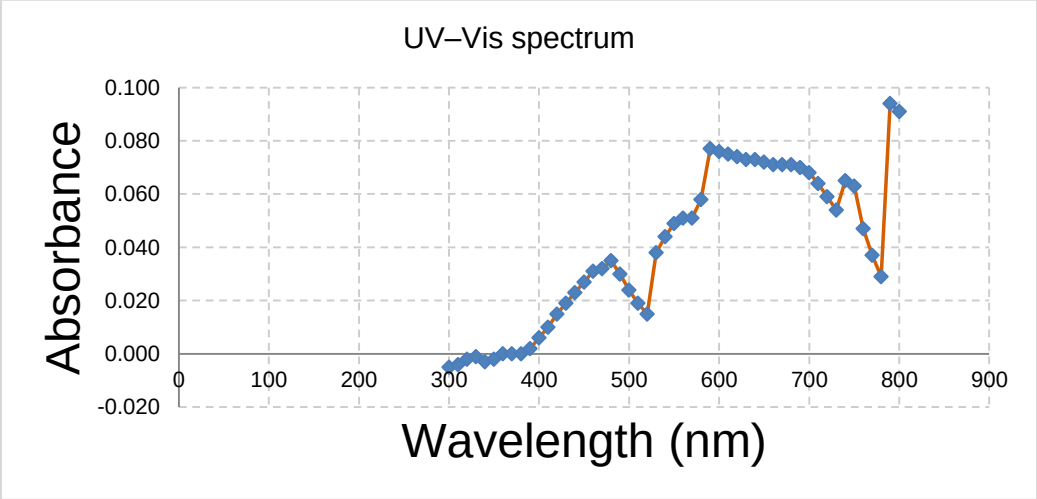


Figure 5. UV–visible absorbance spectra of dopping of titanium dioxide with chitosan is presented from the 51 tabulated readings of sample [23]. Markers indicate values recorded and lines connect between neighboring points

A local maximum of the spectra is located at 480 nm, with an absorbance 0.035. The signal then falls to0.015 at 520 nm before rising to another local maximum at 590 nm, with values of 0.098, 0.077 and 0.076. A large downtrend is seen throughout the higher wavelengths, and a modest increase around 740 nm. Selected readings are identified in Table 2 to enable the plotted comparison to be verified with the numerical record.

Table 2. Selected UV–visible absorbance readings from the measured 10 nm grid [23]. The maximum tabulated value is at 790 nm.

Wavelength (nm)	**MK2**
300	-0.005
400	0.006
480	0.035
520	0.015
590	0.077
700	0.068
780	0.029
790	**0.094**
800	0.091

The samples have the highest tabulated signal at 790 nm, which is 0.117. These values remain high at 800 nm, at0.091. However, the preceding readings at 780 nm are only , 0.029 . Repeat scanning and blank measurement and inspection of the original instrument output should be done in the case of the shared abrupt rise between 780 and 790 nm. The current record sets a high on the sample grid but does not allow for a safe identification of the feature to a specific electronic transition or coating constituent.

The minimum readings occur at 300 nm are −0.005. There are other short-wavelength points where the values are negative and these are also kept in Figure 5. They suggest that there is sensitivity to the reported response at this end of the scan relative to its reference and baseline. These small differences must be interpreted as absolute optical absorption with the aid of a verified blank and the original acquisition geometry.

The available spectra thus indicate a output signal levels for these sample. They do not determine which formulation has a higher concentration of Titanium dioxide nor which sample has a higher photocatalytic activity. The scan is a series of wavelengths and not a concentration – time experiment, so no percentage of dye removed

or the kinetic rate constant is calculated. A maximum at 790 nm is also not an absorption edge, and not converted to a band-gap value.

Conclusions

The spectra have 51 readings, covering the range 300-800 nm. The shared local maximum is at 480 and 590 nm. The largest tabulated values occur at 790 nm and are 0.094. Small negative readings at the short wavelength end and the sudden increase in readings at the long wavelength end are left in the comparison and will need to be verified against the blank and repeat measurements.

The following observations refer to the observed optical response. They still do not have a full physical interpretation as a result of the lack of the specimen formulation, optical geometry and replicate information. Spectra alone cannot identify the band gap of a titanium dioxide; and visible-light photocatalytic cleaning is not proven. The literature-based measurement framework are used to identify how diffuse reflectance, calibrated dye absorbance, and registered stain reflectance can be used to address those questions under matched controls. For discoloration efficiency or kinetics it is necessary to make measurements at different times, and for mineralization, evidence for the product or carbon balance must be provided. The subsequent tests started from a numerical value derived from the measured spectral comparison.

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