QUALITY EVALUATION OF APPLIED PHOTOACTIVE NANOPARTICLE TiO₂ ON TEXTILE FIBRES.

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Abstract

The rapid development of the utilization of photoactive TiO₂ particles, (of about 100 nm in size), and their application onto natural or synthetic textile fibres in addition to glass fibres is the subject of extensive research. The application and particles adherence onto fibres is achieved in various ways. Methods for the monitoring and maintenance of the quality of performance of the particles following application are based on various assessment systems, the majority focusing upon the degradation of organic dyes. The paper describes a method which enables the visualisation of uniformly deposited photoactive TiO₂ nanoparticles on the surface of the textile, and at the same time allows quantification of the performance of the particle. This method is based on the ascorbic acid – dehydroascorbic acid system; during the reaction of ascorbic acid with free radicals generated by the photoactive TiO₂ particles, the yellow-brown coloured dehydroascorbic acid is produced. It is possible to measure the colour parameters of the textile in colour space CIE lab, (change of yellowness index), or statistically evaluate the colouration change.

1 Introduction

It is possible to use textiles with an effectively bound photoactive TiO₂ nanoparticle layer in many areas for functional industrial textile production, (textiles for automobiles, water and atmospheric purification systems etc.), as one-off textile products for use in medicine, textile fabrics for use on public transport, in accommodation, in schools and hospitals, in domestic textiles and clothes featuring anti-bacterial, fungicidal and deodorising properties [1], [2].

The uniform distribution of nanoscale particles on the textile fibre and their fixation on the textile surface is the most important process for functional textile production [3]. It is possible to produce a multifunctional textile by the fixation of TiO₂ nanoparticles with special impregnating agents. At the same time it is necessary protect the textile substrate against photocatalytic degradation and conserve the activity of TiO₂ particles. Methods for the monitoring and maintenance of the performance quality of the particles following application are based on various assessment systems, the majority focusing upon the degradation of organic dyes. These methods for the monitoring of photocatalyses on textile fibres are complicated by the efficiency of the textile substrate to absorb matter, which is quantified in photocatalysis tests.

The degradation of ascorbic acid is utilized for the monitoring and maintenance of the performance quality of the particles. Ascorbic acid is easily converted by interaction with free radicals to form the yellow – brown coloured dehydroascorbic acid [4].
This method is based on the absorption of the yellow – brown coloured dehydroascorbic acid onto the fibres which allows the visualisation of the TiO$_2$ nanoparticle textile covering and simultaneously an evaluation of the function of the particle coating.

2 Experiment

2.1 Materials
During research experimentally prepared TiO$_2$ nanoparticles, (samples from CTC IP laboratories) were used.

The particles were applied in a thin layer upon a polyester and cotton substrate (100% Polyester SPOLSIN 95 kg/m$^2$, Cotton denim 2/1 AMANDA).

The particle coating was applied by water dispersion, the particles being fixed by impregnation in a water bath with binding additives, or alternatively in a bath with hydrophobic additives (samples from INOTEX laboratories).

2.2 Test method
A standard solution of 10% L-ascorbic acid (CAS # 50-81-7, p. a., PENTA) in 50% isopropyl alcohol (CAS # 67-63-0, p. a., PENTA) was prepared.

The textile sample, (a circle of 5 cm in diameter), was immersed in 10 ml of ascorbic acid solution and agitated mechanically for 2 hours. The isopropyl alcohol solution provided the wetting of the textile samples with the hydrophobic treatment.

The textile samples were then air-dried. The appearance of these textile samples following termination of test is seen in Fig. 1.
Fig. 1: The appearance of textile samples

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>VII</td>
<td>VIII</td>
</tr>
<tr>
<td>IX</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
3 Evaluation

3.1 Visual comparison
The textile samples were visually compared according to the intensity of the colouration (sequence in Table 1; where value 1 equates to the lightest sample and value 10 the darkest). The number of tested samples was relatively small (10) as the subjective comparison remained very difficult due to a lack of uniformity in the coloration.

3.2 Measurement of colour values
The colour values of the textile samples were measured using a spectrophotometer - UltraScan Hunter Lab (calibration RSEx, CIE Lab colour space). The delta b* (db*) parameter was evaluated, it being the difference between the b* value of the sample and a standard; (the standard used being a textile sample without TiO₂ particles). Results are shown in Table 1.

3.3 Statistical evaluation
The coloured textile samples were scanned and the colouration was evaluated using statistical software R version 2.11.0. Prelease (rimage package) [5].

The rimage library (imagematrix function) from statistical software R allows the evaluation of the ‘density’ of the textile colouration; this function produces an imagematrix, (the number matrix), from the primary data of a rgb image. Yellow colour is optimal using the blue channel (the additive colour). The image of the numeric matrix (rs) is seen in Fig. 2.

![Image of numeric matrix](image)

Fig. 2: image of the numeric matrix (rs)

The special math function produces the total colour depth values in each row and each column, and the average (mean_row, mean_col ) and standard deviation (sd_row, sd_col) of the colour depth. The higher the intensity of the colouration the lower the value of the average, (the closer to black, then the closer to zero). Greater variation of the colouration produces a higher value of standard deviation. Results are presented in Table 1.
Table 1: the row and column averages and the standard deviation of the colour depth; visual comparison according to colouration intensity.

<table>
<thead>
<tr>
<th>textile sample ID</th>
<th>db*</th>
<th>sequence of samples(^a)</th>
<th>mean_row</th>
<th>sd_row</th>
<th>mean_col</th>
<th>sd-col</th>
</tr>
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<tbody>
<tr>
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<td>9</td>
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<td>5,57</td>
<td>227,04</td>
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<td>241,06</td>
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<tr>
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<td>3,26</td>
<td>276,58</td>
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<tr>
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<td>5,65</td>
<td>260,55</td>
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<tr>
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<td>5,98</td>
<td>242,45</td>
<td>5,11</td>
</tr>
</tbody>
</table>

We compared both numerical evaluation and the subjective comparison of samples in the series according to colouration intensity, by way of the matrix graph (Fig. 2).

Fig. 2: matrix graph

\(^a\) value 1 equates to the lightest sample and value 10 the darkest
The matrix graph (Fig. 2) illustrates that

- the $b^*$ value, the average colour depth and the sequence of visually evaluated samples both correlate strongly
- the $b^*$ value and the sequence of samples do not correlate with the standard deviation
- the standard deviation by rows and by columns shows no close correlation (correlation coefficient being only 0.67)

Both ways of evaluation, (colour value measurement and statistical evaluation of colour depth), quantify the textile colouration intensity well. The higher $db^*$ value or the lower average colour depth value relate to a higher colouration intensity and so a more effective photoactive TiO$_2$ nanoparticle layer.

From the $db^*$ value can not be evaluated the non-uniformity of the colouration. The uniform coating of the photoactive TiO$_2$ layer on the textile substrate is noticeably evaluated and quantified by the standard deviation of the colour depth, expressed by the rows and columns, (whereby bigger and more frequent stains, thereby a higher standard deviation and also the difference between the deviation across the rows and columns).

Acknowledgement:

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References

[2.] The future is...Testiles!. EURATEX Brussels, June 2006