IMPROVED ATTACHMENT OF TITANIUM DIOXIDE NANOPARTICLES ON COTTON FABRIC USING PLASMA TREATMENT AND CHITOSAN COATING

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Abstract

In this study plasma treatment and subsequent chitosan coating were considered as pretreatments to improve the loading and fastness of titanium dioxide nanoparticles on cotton fibers. The surface morphology of raw, plasma treated, chitosan coated and TiO₂ functionalized samples were analyzed using scanning electron microscopy. The self cleaning property and antibacterial activity of the finished samples were also evaluated. The plasma treated cotton samples coated with chitosan and then finished with TiO₂ nanoparticles showed high self cleaning and antibacterial activities.

Introduction

TiO₂ nanoparticles are widely applied on textiles for obtaining functional properties like self cleaning, antibacterial etc. Several studies have been reported regarding the immobilization of TiO₂ nanoparticles on fabric surfaces via coating, sol–gel, or surface modification methods by introducing hydroxyl or carboxyl groups onto the surface of the fabric. The loading and stable attachment of the nanoparticles on the fibers is usually a major problem [1]. Several reports suggested that the problem of stability and durability of these nanoparticles can be overcome by plasma fictionalization i.e. introduction of new functional groups to the fiber surface which facilitates the binding of colloidal nanoparticles to fibers [2-3]. Plasma treatment also can improve the attachment of chitosan to cotton fibers [4]. In this study, low pressure oxygen plasma has been used to enhance the loading of chitosan biopolymer and TiO₂ nanoparticles onto cotton fibers with the aim of wash-fast antibacterial and self cleaning properties.

Experimental

Plasma treatment: Plain woven pure cotton fabric was cut to size 10*15 cm². The samples were pretreated using radio frequency low pressure plasma equipment
(Junior plasma, Europlasma, Belgium) with oxygen gas (chamber pressure: 100 mTorr; oxygen flow rate: 100 sccm; plasma power: 150 W; time: 5 minutes).

Chitosan treatment: Plasma treated samples were immediately impregnated with 0.5% w/v solution of chitosan containing 1% v/v acetic acid for 30 min. Padding with 100% wet pick up, drying at 80 °C for 30 min and washing (1% w/v Triton X-100 in distilled water, at 50 °C for 15 min) were the next steps of the coating process.

TiO$_2$ nano-finishing: The samples were padded with a 1% wt. colloidal solution of TiO$_2$ nanoparticles (100 % wet pick up) and dried at 80 °C for 30 min and washed.

Scanning electron microscopy, self cleaning and antibacterial tests besides the determination of residual nanoparticles after laundering were performed according to the methods previously used by Hashemizad et al [5].

**Results and Discussion**

Figure 1 confirms the slight etching of cotton surface after plasma treatment, coating of cotton fibers with chitosan and attachment of TiO$_2$ nanoparticles.

![Figure 1. SEM images of raw (1), plasma treated (2), chitosan coated (3), and nano TiO$_2$ coated (4) cotton fibers](image)

Raw, plasma treated and chitosan coated cotton fabrics were finished with TiO$_2$ nanoparticles separately. Figure 2 shows that the plasma treated and chitosan coated sample contained the highest amount of TiO$_2$ nanoparticles and had the best wash fastness after 10 washing cycles.
The above mentioned sample showed the highest color change (ΔE) when stained with methylene blue and subjected to daylight irradiation for 12 hours and exhibited very good antibacterial activity (figure 3).

<table>
<thead>
<tr>
<th></th>
<th>Before laundering</th>
<th>After laundering</th>
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<tr>
<td>Chitosan coated</td>
<td>5</td>
<td>4,5</td>
</tr>
<tr>
<td>Plasma treated</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Raw</td>
<td>1,5</td>
<td>0,5</td>
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</tbody>
</table>

**Figure 2.** Percent TiO$_2$ on different finished samples

**Figure 3.** The growth of *E. coli* on raw cotton (left) and TiO$_2$ finished (right) sample after plasma and chitosan treatments

**Conclusion**

In this study cotton fabric was functionalized using chitosan and TiO$_2$ nanoparticles after oxygen plasma pretreatment. The plasma treatment increased the attachment of chitosan on the surface of cotton fibers. The chitosan coated sample showed increased and more wash fast attachment of the nanoparticles. The finished sample showed good self cleaning property and high antibacterial activity against Gram-positive and Gram-negative bacteria.
References

1. Yu, Ming; Wang, Ziqiang; Liu, Hanzhou; Xie, Siyuan; Wu, Jingxia; Jiang, Haiqing; Zhang, Jianyong; Li, Linfan; Li, Jingye: ACS Applied Materials & Interfaces (2013), 5 (9), 3697-3703.


