Effect of Nano-TiO_2 Particles Surface Modification on Antibacterial Properties of Cotton Fabrics

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Abstract: The dispersion property of modified nano-TiO_2 particles and its antibacterial properties on cotton fabrics were studied. The results show that the stability of nano-TiO_2 solgel was related to the concentration of the modifier and the pH values of the system. The experimental result shows that washing fastness of the finished fabric treated with modified nano-TiO_2 had been increased and the antibacterial property of finished fabric was also related to the concentration of the modifier.

Keywords: Nanotitanium dioxide, modifier, properties, cotton fabric, washing durability, antibacterial finishing.

1. Introduction

In recent years, nanotechnology has been flourishing. The development of nano materials is a foundation for the development of nanotechnology. Nano materials refer to materials with special properties, whose geometric dimension reaches nano scale [1, 2]. Among nano materials, great importance has been attached to nano oxide. Nano oxide has a promising application prospect in textiles due to its outstanding characteristics [3, 4]. A typical example is the photocatalysis and ultraviolet absorption properties of nano-TiO_2 that can be utilized in antibacterial finishing and anti-ultraviolet finishing of textiles to meet the demand of multi-functional finishing of textiles [5, 6]. However, nano-TiO_2 particles have very high surface energy. When they are distributed in the medium, multi-phase thermodynamically unstable system will be formed, and nano particles will agglomerate and precipitate. Therefore, an essential problem to solve in order to facilitate the application of nano oxide in the field of after-finishing of textile products is to improve the stability of nano oxide particles in medium [7].

Nano oxide is a kind of inorganic compound in lack of functional groups which can react with textile materials directly. During the after-finishing processing of the fabrics, adhesives are utilized to paint nano oxide on the surface of the fabrics. This leads to an inferior touch feel and wash fastness. In order to improve the stability of nano oxide in various media and facilitate the application of nano materials, a most effective way is to modify the surface of nano particles [8, 9]. In this article, nano-TiO_2 surface is modified with surface modifier to improve the stability of nano particles in disperse system. Meanwhile, large numbers of reactive groups are introduced on the surface of nano-TiO_2 [10, 11]. During the antibacterial finishing and processing of the fabrics, these reactive groups can react with relevant groups through grafting agent in the finishing solution or directly form covalent bond to render superior wash fastness to the fabric after finishing.

2. Experimental materials and methods

2.1 Materials and reagents

Nano-TiO_2: industrial product; surface modifier: self made silicon compound with multi-active group; grafting agent with double-active group: self made; sodium hydroxide, hydrochloric acid, glacial acetic acid, ethylene glycol etc. all of these reagents are chemically pure or analytically pure.

Fabric: 30×30(68×68) pure cotton dyed sheeting.

Experimental strains: golden yellow staphylococcus, Escherichia coli.

2.2 Apparatus

High-shearing mixer, sedimentation balance (self-refitted), electrophoresis apparatus, motor-padder, UV spectrophotometer.

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2.3 Experimental methods

2.3.1 Surface modification of Nano-TiO_2 particles

Certain amount of nano-TiO_2 was distributed in ethylene glycol using the high-shearing mixer and ultrasonoscope, and proper surface modifier was added to the solution. After certain reaction time, modified nano-TiO_2 was formed.

2.3.2 Antibacterial finishing of the fabrics

Stable finishing solution was prepared with modified nano oxide, crosslinking agent or grafting agent, dispersant, pH regulator etc. The fabric was treated with double-dip and double-nip technology (picking up ratio is 80%). It was then pre-baked for 2-4 minutes at 100℃, and baked for 2-4 minutes at 130-160℃.

2.4 Test methods

2.4.1 Infrared spectrum analysis

AVATAR 370 FT-IR (America Thermo Nicolet Company), ATR attenuated total reflectance, 32 times of scanning, and 4cm^{-1} resolution.

2.4.2 Stability test of nano-TiO_2 solgel

2.4.2.1 Still-setting method

The modified nano-TiO_2 was distributed in ethylene glycol using high-shearing mixer and ultrasonoscope to form the modified nano-TiO_2 solgel with a nano-TiO_2 concentration of 200g/L. The prepared solgel was poured into a capped measuring cylinder, and the layer heights of solgel at different time points were measured.

2.4.2.2 Sedimentation method

The above-mentioned solgel was poured into the measuring cylinder, the sedimentation quantities of nano particles at different time points were determined using the self-refitted sedimentation balance, and the sedimentation rate was calculated according to the formula (1).

$$Q(\%) = \frac{W}{W_0} \times 100\% = \frac{W}{H \times C \times A} \times 100\% \quad (1)$$

In formula (1), Q is the sedimentation rate (%) within certain time. W is the weight (mg) of nano particles on the sedimentation pan within certain time. W_0 is the total weight (mg) of the nano particles in the solgel above the sedimentation pan. H is the height (cm) from sedimentation pan to the liquid surface. C is the nano particle content (mg/cm^3) of in the solgel. A is the area (cm^2) of sedimentation pan.

2.4.3 Determination of Zeta electric potential

The nano-TiO_2 solgel was poured into the electrophoresis tube, and the electrophoretic velocity of the solgel at certain voltage was measured. The Zeta electric potential was calculated according to the formula (2) [12].

$$\xi = \frac{4\pi\eta \frac{l'}{t}}{D\frac{E}{l}} \times 300^2 \quad (2)$$

In formula (2), η is the viscosity of the dispersed medium, D is the dielectric constant of the dispersed medium, E is the voltage (volt) added between two electrodes, *l* is the distance (cm) between the two electrodes, ξ is the Zeta electric potential (volt), l' is the travel distance (cm), and t is the time (seconds).

2.4.4 Determination of wash fastness

According to the JIS217-103 standard, the bath ratio used was 1:40, the powdered soap content used was 2g/L and the water temperature was 35°C. Washing was carried out once in every 5 minutes, followed by rinsing, dehydration and air drying.

2.4.5 Antibacterial performance test [13, 14, 15]

The bacterial liquid was inoculated onto the sterilized finished fabrics, and was incubated for 20 hours at 37°C. The fabrics were washed with buffer solution. The washing solution was then diluted under different dilutions, which were then inoculated onto the sterilized plates as well as the agar culture. After 48 hour incubation time at 37°C, the number of the colonies formed was counted. Control experiments were carried out at the same time.

$$\text{Percent decrease of bacteria (\%)} = \frac{B - A}{B} \times 100\% \quad (3)$$