Influence of Nano-TiO_2 Photocatalyst on Physical and Chemical Properties of Cotton Fiber

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Abstract: The aim of this work is to research the performance of nano TiO_2 photocatalyst on physical & chemical properties of cotton fiber. Different concentration of photocatalyst was finished on the cotton fabric by finishing process. The UV light and the natural light were used as the light source to irradiate the fabric. By determining the fiber's polymerization degree, crystallinity, as well as the fabric's breaking strength, tear strength and K/S value, the influence of the nano TiO_2 photocatalyst on the physical & chemical properties and the colour of the cotton fiber were measured.

Keywords: Nano $TiO_{2,}$ photocatalys, cotton fiber, physical properties, chemical properties, after- treated.

1. Introduction

Nano-TiO_2 is a kind of N-type semiconductor material [1,2] with wide forbidden bandwidth (3eV or so). When nano-TiO_2 is treated with ultraviolet (UV) irradiation, due to higher energy level of the UV light than nano-TiO_2, the electrons of nano-TiO_2 are excited and transited from the valence band onto the conduction band to form electron (e^-) hole (h^+) pair. The relevant formula is as follows:

$$TiO_2 + hv \rightarrow TiO_2 + h^+ + e^-$$

When TiO_2 is absorbed by air and water vapor,, the hole (h^+) reacts with H_2O and hydroxyl free radical ·OH is formed:

$$H_2O + h^+ \rightarrow \cdot OH + H^+$$

The electron (e^-) will react with oxygen molecule absorbed on the surface and produce superoxide anion free radical ·O_2^-:

$$e^- + O_2 \rightarrow \cdot O_2^-$$

In addition, the following reaction occurs:

$$O_2^- + H^+ = \cdot OOH$$

Wherein, the reaction products such as ·OH, ·O_2^- and ·OOH are active free radicals with strong oxidizability. They can destroy chemical bonds such as C-C, C-H, C-O, O-H, N-H in organic-compounds and decompose organic macromolecules into small molecule such as CO_2, H_2O, which leads to the conclusion that nano photocatalyst TiO_2 possesses the ability to oxidize and decompose various organic compounds and some inorganic compounds. Consequently it can destroy cell membrane of bacteria, solidify the virus proteins, and form permanent antibacterial and antifouling coating on the surface of the materials. Therefore it possesses strong antifouling, sterilizing and deodorizing functions [3]. In the field of air pollution, photocatalysis technology can also effectively treat pollutants such as nitrogen oxides, sulfur oxide, VOC etc. [4]. Therefore, nano photocatalyst can be widely used in the areas of air purification, sewage treatment, anti-bacteria and antifouling, textile fibers etc. [5].

The normal way to apply nano TiO_2 photocatalyst (PC) onto fabrics is to utilize solution blending and melt blending methods to mix nano particles with polymers to prepare functional fibers and fabrics. Alternatively nano particles can be painted using adhesives evenly on fiber or fabric surface to produce functional textile [4]. Both of these exhibit problems such as how to make textile surface display photocatalyst functions and the possible deterioration of the fiber materials due to the presence of the photocatalysts. Because of the strong oxidizability of the photocatalyst, the fiber macromolecules can be easily broken so that the end group number of molecular chain of amorphous part of fiber increases and the supermolecular structure of the fiber weakens. This finally results in a decrease of macro mechanical property of the fibers [6-8].

At present, the other studies for functional finishing of textile with the nano-TiO_2 photocatalyst are not

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related to the modified nano-titanium dioxide, but also not related to the article in which it was published.

This article mainly focuses on the change of the polymerization degree, crystallinity, breaking strength, tearing strength and color of the cotton fiber after being treated with nano photocatalysts and it provides a foundation for developing textile products with photocatalytic functions.

2. Experimental materials and methods

2.1 Materials

Fabrics: pure grey cotton cloth 20×20 (piece number), 60×60 (density).

Reagents: self-made modifier nano-TiO_2 photo-catalyst Nano-PC hydrosol fabric finishing agent, color and flavor free, particle diameter is <100nm, and the concentration is 10%; the rest of the reagents are of commercial grade AR and CP.

2.2 Fabric finishing method with photo-catalyst

The fabric was treated with Nano-PC photocatalyst finishing solution with a Nano-PC concentration of 0.2%~1.0%. It was treated with double-dip and double-nip technology (picking up ratio is controlled at 80%), pre-baked for 5 minutes at 65℃, and bake for 10 minutes at 80~100℃.

2.3 Test methods

2.3.1 Irradiation treatment of the fabric finished with photocatalyst with different light sources

2.3.1.1 Irradiation with natural light as a light source

The cotton cloth finished with photocatalyst reagent was spread flat on the experimental bench, irradiated directly with sunlight. The irradiation time ranged from one week to several months.

2.3.1.2 Irradiate with UV light as a light source

The cotton cloth finished with photocatalyst reagent was spread flat on a clean bench, irradiated with 15W UV light tube. The irradiation time ranged from 24 hrs to 120 hrs according to JIS standard.

2.3.2 Determination of the polymerization degree of cotton fiber [9,10]

Cuprammonium solution method was used. The viscosity of the solution was determined with Ubbelohde viscosity meter, and the polymerization degree of cotton fiber was calculated:

$$[\eta]=\frac{\eta_{sp}}{C}=\frac{\eta_{sp}}{0.11\times(1-\phi)}=\frac{t_1-t_0}{0.11\times t_0\times(1-\phi)} \quad (1)$$

Wherein: ϕ –fiber moisture regain with experimental determination; t_1, t_2 – the sample solution and blank solution through the capillary viscometer Ubisch time respectively.

Formula for calculating the average degree of polymerization:

$$\overline{DP}=\frac{[\eta]}{K}=\frac{[\eta]}{5\times10^{-3}}=200\times[\eta] \quad (2)$$

Wherein: $\overline{DP}$ is the average degree of polymerization of cotton fiber; K is constant of cotton fiber in cuprammonium solution.

2.3.3 Determination of K/S value

Color Quest XE-type color measuring and matching apparatus was used to determine the K/S value.

2.3.4 Breaking strength and tearing strength

The breaking strength of the fabric was determined using the YG (B) 026D-250 type electronic fabric strength tester. The tearing strength of fabric was determined with YG033 fabric tearing apparatus.

2.3.5 Determination of the crystallinity of the cotton fiber

The fiber crystallinity was determined using D/MAX-2000 X-ray diffractometer of Japan Rigaku Company. An X-ray tube was used as copper target. It was used to radiate copper K_α, the voltage was 40kV, the current was 40mA, and the wave length λ was 0.15406 nm. The fiber crystallinity was calculated using Segal [11] emiridal method:

$$C_{rI}\%=[(I_{002}-I_{am})/I_{002}]\times100 \quad (3)$$