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Application of Nano-ZnO on Antistatic Finishing to the Polyester Fabric

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Abstract

Settlement experiment was employed to estimate the dispersion of nano-ZnO in aqueous solution, which was surface modified with different surfactants, through the deposition time. And suitable surfactant was selected to improve the dispersion effect. Antistatic finishing agent, which was compounded with nano-ZnO, was applied to polyester fabric by pad-dry-cure process and the optimal processing conditions were obtained by orthogonal test: the concentration of finishing agent was 1.0%, soaking time was 5 min, curing temperature and time were 180°C and 3 min respectively. By the static test, the results showed that the antistatic property of the treated fabric was better.

Keywords: Nano-ZnO, Surfactants, Polyester fabric, Antistatic finishing, Orthogonal test

1. Introduction

Zinc oxide powders are materials for a wide range of applications, because it possesses unique photocatalytic, electrical, optical and antibacterial properties and is a biofriendly absorber (Chen, 2006, p.434; Alessio, 2007). In recent years, nano-ZnO, which shows special physical and chemical properties to bulk particles, becomes a new solid material (Alessio, 2007; Chen, 2006, p.434; Zhu, 2007). ZnO nanoparticles are prepared by different synthesis approaches, including hydrothermal, mechanochemical, sonochemical, chemical precipitation, sol-gel, spray-pyrolysis, microemulsion, solution combustion, solid state reaction and laser induced chemical methods (Chen, 2006, p.434; Wang, 2006, p.40). But direct precipitation method is widely used, owing to the advantages of easy operation, low require to the equipment, high purity product and lower cost (Liao, 2003, p.22). Currently, the application of nanotechnology in the textile industry has increased rapidly. The fabrics are treated with the nanoparticles as finishing agent, that result in textile materials producing different performances (Alessio, 2007). In this paper, the surface treatments of nano-ZnO were carried out with different surfactants to improve the dispersion of nano-ZnO in aqueous solution and prepare antistatic finishing agent. In order to evaluate the antistatic performance of the treated textiles, then nanometer antistatic finishing agent, which was prepared with nano-ZnO, was applied to polyester fabric (Alessio, 2007).

2. Experimental

2.1 Materials

Nano-ZnO was prepared according to the literature (Liao, 2003, pp.22-23). Surfactants and 106 binder were obtained from market and were used without any further purification. The mass per unit surface was 150 g/m2 for white polyester fabric, which was used as received (Alessio, 2007).

2.2 Method

2.2.1 The choice of surfactants (Cui, 2001)

Different amount of cationic surfactant A, anionic surfactant B, nonionic surfactant C and amphoteric surfactant D were added into the aqueous of nano-ZnO, respectively. With the ultrasonic vibration, the solution was dispersed uniformly, which was placed at colorimetric tube and kept to observe the deposition time of nano-ZnO in aqueous solution.

2.2.2 The preparation of nanometer antistatic finishing agent

A certain amount of nano-ZnO, surfactant and binder were added into distilled water, and then the mixture was mixed well under stirring, that was the nanometer antistatic finishing agent with a certain concentration (Li, 2006, p.265).

2.2.3 Fabric treatments

Two dipping androlling → drying (80°C, 1 min) → curing.

2.2.4 The Orthogonal design

The polyester fabric was finished with antistatic finishing agent, which was compounded with nano-ZnO, its main

factors: solution concentration, soaking time, curing temperature and time. The four factors four levels orthogonal test table L16 (45) was adopted to obtain the optimal finishing process. The factor levels of orthogonal test are shown in table 1(Zhang, 2006, p.15).

2.3 Measurements

2.3.1 TEM of nano-ZnO

The morphology and size of the ZnO products were characterized by a Hitachi Model H-7650 transmission electron microscope (TEM) (Tang, 2006, p.548).

2.3.2 The fabric static test

The charge density of the untreated and treated fabric was measured according to a standard method (Professional Standards of the People's Republic of China ZB W 04008-89) (Alessio, 2007).

2.3.3 The fabric whiteness test

The whiteness of the untreated and treated fabric was performed by a WSD—3U fluorescent whiteness meter.

3. Results and discussion

3.1 TEM analysis of nano-ZnO

Small dimension, large surface area and high surface energy of nano-ZnO result in agglomeration, especially when the synthesis is carried out in an aqueous medium (Luo, 2003, p.27; Alessio, 2007). Therefore, in order to improve the dispersion of nano-ZnO in aqueous solution, the reaction conditions of nano-ZnO preparation were discussed and the optimal reaction conditions were obtained. TEM image of the nano-ZnO that was prepared with the optimal reaction conditions is shown in Fig. 5. Nanoparticles with good dispersion were nearly spherical and their diameters were between 20 and 40 nm.

3.2 The impact of different surfactants on the dispersion of nano-ZnO in aqueous solution

Nanoparticles easy to agglomeration, that due to their properties of small dimension, large specific surface area, and high surface activity (Luo, 2003, p.27). Surfactants added into aqueous solution will decrease contact angle of solid particles that are dispersed in aqueous solution, be beneficial to the particle swarm fragmentation and increase the energy barrier of particles to prevent reagglomeration of the dispersed particles (Xia, 1997, p.107). Particle's settling velocity in dispersion medium is related to size and quality of the particle. The larger the particle, the higher settling velocity it is (Ni, 2006). Therefore, the changes of aggregation degree, the dispersion state and the aggregation of the modified nano-ZnO in aqueous solution were qualitatively detected through the deposition time. The results show that the deposition time is longer, the dispersion is better and the agglomeration among particles is harder (Cui, 2001, p.99).

(1) The deposition time of aqueous solution containing nano-ZnO is 10 days by adding cationic surfactant A, but which will not be applied to practical application because the results are unstable.

(2) With the increase of addition amount of the anionic surfactant B, the deposition time of nano-ZnO in aqueous solution present a trend of first increase then decrease, which is shown in Fig. 2. When its adding amount is 40 drops, the dispersion of nano-ZnO in aqueous solution is significantly improved that the deposition time is 218 h.

(3) The deposition time of 18 h means the stability of nano-ZnO in aqueous solution is not improved obviously when the nonionic surfactant C is added.

(4) With the increasing of amphoteric surfactant D added into aqueous solution containing nano-ZnO, nano-ZnO can be completely dissolved that result in forming thermodynamic stable and isotropic transparent solution, which owns stable character even placed for long time.

By comparing the effects of the four kinds of surfactants on the dispersion of nano-ZnO in aqueous solution, the choice was amphoteric surfactant D. This is because the micellar solubilization of amphoteric surfactant D on the nano-ZnO in aqueous solution (Xia, 1997, p.109) is convenient for the application of nanometer antistatic finishing agent in fabric finishing.

3.3 The orthogonal test results of functional finishing of the fabric

3.3.1 Fabric antistatic property

The charge density of the fabrics, which are finished according to the factors and levels of orthogonal test, are shown in table 2.

Orthogonal test analysis shows that the greater the range, the greater the impact of the factor on the experimental index (Zhang, 2006, p.15). The concentration of finishing agent has the most influential effect on the charge density, other ranked as follows: Soaking time, baking temperature and baking time, which are shown in table 2. The comparation among the average of various level index reflects influence effect of the level on the index, that means the k_n is smaller,

the level is better (Zhang, 2006, p.15). When the concentration of finishing agent is 0.5%, the charge density of the treated fabric is smaller based on the comparison of K_n^A. However, in this case, a caking phenomenon of the binder is occurred in the finishing agent, that has an adverse effect on practical application. Considering the K_n and application, the optimal finishing process was obtained: the concentration of finishing agent 1.0%, soaking time 5 min, baking temperature 180 °C and baking time 3 min.

3.3.2 The fabric whiteness

As can be seen from table 3, the hunter whiteness of the treated fabric with different treatment is slightly increased in comparison with the original piece, but the change is not obvious. This is because the properties of the surfactant and adhesion agent in finishing agent have no change via pad-dry-cure process, and the transparent and compact film, which doesn't generate virtual effect on the optical properties of the fabric, is formed on the surface of the fabric (Xu, 2005, p.68).

4. Conclusions

To nano-ZnO, amphoteric surfactant D owing micelle solubilization as dispersing agent is used to prepare nanometer antistatic finishing agent. And the best processing conditions of polyester fabric treated with the finishing agent that are the concentration of finishing agent 1.0%, soaking time 5 min, curing temperature 180°C and curing time 3 min are obtained by orthogonal test.

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Table 1. The factor levels of orthogonal test

Levels	Concentration of nano-ZnO (A)	Soaking time (B) /min	Curing temperature (C) /℃	Curing time (D) /min
1	0.5%	5	120	0.5
2	1.0%	15	140	1.5
3	1.5%	30	160	3
4	3.0%	40	180	4

Table 2. Orthogonal test table and analytical results of charge density

Factors	A	B	C	D	Charge density×10^{-8}/ C·m-2
1	1	1	1	1	5.2
2	1	2	2	2	3.5
3	1	3	3	3	9.5
4	1	4	4	4	15
5	2	1	2	3	38
6	2	2	1	4	41
7	2	3	4	1	50
8	2	4	3	2	22
9	3	1	3	4	77
10	3	2	4	3	61
11	3	3	1	2	160
12	3	4	2	1	130
13	4	1	4	2	170
14	4	2	3	1	280
15	4	3	2	4	250
16	4	4	1	3	230
k1	8.3	72.6	109.1	116.3	
k2	37.8	96.4	105.4	88.9	
k3	107	117.4	97.1	84.6	
k4	232.5	99.3	74	95.8	
R	224.2	44.8	35.1	31.7	

Table 3. Hunter whiteness of the different samples and their relative change percentage

Samples	Hunter whiteness /Wh	Relative change percentage
1	85.45	1.05%
2	86.05	1.76%
3	87.25	3.18%
4	86.97	2.85%
5	86.04	1.75%
6	85.32	0.90%
7	86.87	2.73%
8	86.84	2.70%
9	86.25	2.00%
10	88.71	4.91%
11	84.77	0.25%
12	84.75	0.22%
13	88.65	4.84%
14	86.09	1.81%
15	85.83	1.50%
16	86.06	1.77%
Original piece	84.56	

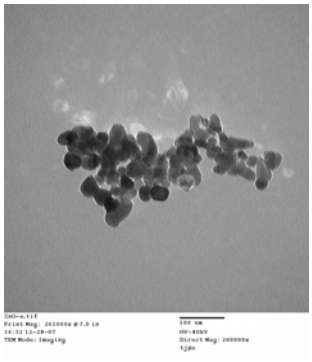

Figure 1. TEM photograph of nano-ZnO

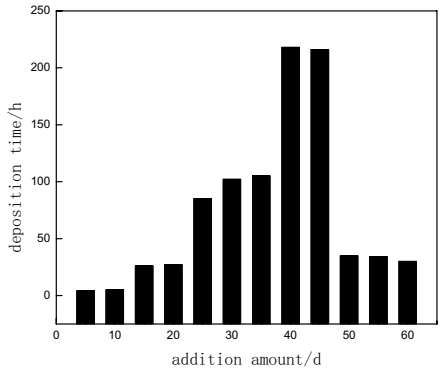

Figure 2. Effect of addition amount of the anionic surfactant B on nano-ZnO deposition time