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Static properties and moisture content properties of polyester fabrics modified by plasma treatment and chemical finishing

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Abstract

Low temperature plasma treatment has been conducted in textile industry and has some success in the dyeing and finishing processes. In this paper, an attempt was made to apply low temperature plasma treatment to improve the anti-static property of polyester fabric. The polyester fabrics were treated under different conditions using low temperature plasma. An Orthogonal Array Testing Strategy was employed to determine the optimum treatment condition. After low temperature plasma treatment, the polyester fabrics were evaluated with different characterisation methods. Under the observation of scanning electron microscope, the surface structure of low temperature plasma-treated polyester fabric was seriously altered. This provided more capacity for polyester to capture moisture and hence increase the dissipation of static charges. The relationship between moisture content and half-life decay time for static charges was studied and the results showed that the increment of moisture content would result in shortening the time for the dissipation of static charges. Moreover, there was a great improvement in the anti-static property of the low temperature plasma-treated polyester fabric after comparing with that of the polyester fabric treated with commercial anti-static finishing agent.

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Keywords: Low temperature plasma; Polyester; Anti-static; Moisture content

1. Introduction

Static is non-movable and so the generated static charges localised on the surface of the materials are not able to be removed [1–3]. In the case of conductive material, e.g. metal, the charges may conduct to some places else and leak in the air. As for textile material, the textile fibres are non-conductive in nature and so the generated static charges will stay on the surface for longer time thereby creating a serious static problem [4,5]. The static problem is commonly found in synthetic fibre, especially polyester fabric and is significant in dry and low humidity condition [6,7]. Generation of static charges is accomplished by motion such as rubbing fabric, walking on carpet and sitting down etc. During this movement, the fabric surfaces contact with each other, resulting in the generation of positive charges on one surface and negative charges on the other surface. The generated and accumulated charges will stay on the fabric and make the wearer uncomfortable. Static charged fabrics are always covered with dust suspended in air and cause dusting problem. In some extreme case, sufficient amount of static charges may generate sparks and cause fire explosion [5].

Generally speaking, natural fibres have less static problem than synthetic fibre. Some evidences show that natural fibre has a higher degree of amorphous region than synthetic fibre, and this will greatly increase the charge dissipation in air. As for polyester, it has lower degree of amorphous region and higher degree of crystalline region, resulting in lower moisture regain. Hence, polyester has the most significant static problem. There are two basic methods used for eliminating or solving the static problem. The first method is to inhibit the charge generated on the

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fabric by coating a conductive polymer or layer on the textile surface [8]. On the contrary, the second method is to increase the rate of dissipation of static charges in air. In this paper, low temperature plasma treatment is employed to modify the surface of the polyester fabric [6,7] aiming to improve the moisture content of the polyester fabric and increase the rate of static charge dissipation in air [9–11].

Hence, the aims of this paper are to study the effect of low temperature plasma treatment on the static property of polyester fabric and also to find out the optimum treatment condition for obtaining the best anti-static property. In addition, a comparison of anti-static property will be made between the low temperature plasma-treated polyester fabric and the polyester fabric treated with commercial anti-static finishing agent.

2. Experimental

2.1. Materials

White polyester plain weave fabric (100%) of 77 g/m^2 with 49 ends/cm (8.4 tex) and 38 picks/cm (8.7 tex) was used in this study. The fabric was washed with 2% non-ionic detergent at pH 7 and 40 °C for 20 min, and then rinsed with deionised water for about 5 min so as to remove any oil or impurities that might deposit on the fabric surface randomly during the manufacturing processes. The clean fabric samples were conditioned at the relative humidity of 65 ± 2% and 21 ± 1 °C for at least 24 h prior to all experiments.

Table 1
Parameters and levels used in OATS

Level	Parameters		
	Discharge power (W)	System pressure (Pa)	Treatment duration (min)
I	200	100	3
II	100	50	2
III	50	25	1

2.2. Parameters for optimising low temperature plasma treatment

Low temperature plasma treatment was conducted by a glow discharge generator (Showa Manufacturing Co. Ltd., Japan), a radio-frequency (13.56 kHz) etching system, using oxygen as the plasma gas. In order to achieve the most excellent effect of low temperature plasma on the anti-static property of the polyester fabrics, the optimisation of low temperature plasma treatment was investigated. An Orthogonal Array Testing Strategy (OATS) technique was applied to analyse the optimum treatment condition [12–14]. Three variables in the low temperature plasma treatment, i.e. discharge power, system pressure and treatment duration, were used and the details of experimental arrangements are shown in Tables 1 and 2 respectively. After low temperature plasma treatment, the fabric samples were conditioned at the relative humidity of 65 ± 2% and 21 ± 1 °C for at least 24 h prior to further evaluation.

2.3. Anti-static property

The anti-static property of the fabric samples in both warp and weft directions was determined by means of a STATIC voltmeter R-1020 (Rotchschild, Swiss) using resistance measurement. The fabric samples were first charged-up and then the elapsing time was measured. The elapsing time, expressed as half-life decay time, is the time required for discharging half of the charge present

Table 2
Orthogonal table for optimising the low temperature plasma treatment for improving anti-static property of polyester fabric

Test run	Parameters			Half-life decay time (s)
	Discharge power (W)	System pressure (Pa)	Treatment duration (min)	
1	I	I	I	354
2	I	II	II	334
3	I	III	III	320
4	II	I	II	408
5	II	II	III	465
6	II	III	I	322
7	III	I	III	502
8	III	II	I	381
9	III	III	II	406

$\sum$ Change in half-life decay time (s)	Parameters		
	Discharge power (W)	System pressure (Pa)	Treatment duration (min)
$\sum$ I	**1008**	1264	**1057**
$\sum$ II	1195	1180	1148
$\sum$ III	1289	**1048**	1287
Difference	*281*	*216*	*230*

Figure in Bold exhibits the greatest value among all the values shown in the levels of different factors used while the Italic shows the level of importance of each factor.