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Plasma treatment of polyester fabric to impart the water repellency property*

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Abstract. Polyester fabric is treated with DCDMS solution by two methods: dipping the fabric directly in DCDMS solution for different intervals and dipping the fabric in DCDMS solution after its exposure into RF plasma chamber for different durations at optimized exposure power conditions. The physical properties of polyester fabric treated with DCDMS in the presence or absence of air plasma have been compared with control fabric. Different characterization techniques like scanning electron microscope, attenuated total reflectance-IR and Dataflash 100 colour measurement spectrophotometer are used to assess the surface morphology, composition and change in colour parameters. Water repellency property of both untreated and modified polyester fabric is studied using AATCC test method 39 (1971). The effectiveness of the water repellency property of modified polyester fabric is checked by repeated washing up to ten cycles.

Keywords. Polyester; dichlorodimethylsilane; plasma; water repellency.

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1. Introduction

Textile materials treated under the influence of plasma modify the uppermost layers of the substrate and leaves the bulk characteristics unaffected, which further results in desirable surface modification like surface etching depending on the choice of optimized plasma conditions [1–6]. Attempts have been made to develop an apparatus for continuous low pressure glow discharge plasma treatment with a view to achieve printability of pattern on woolen cloth, which was implemented as a

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pilot production line [7]. It is found that prior plasma treatment not only modifies printability of the wool but also saves production cost in the entire process and hence increases profitability, resulting in a more eco-friendly and viable process.

It has been observed that treatment of textile materials with dichlorodimethylsilane (DCDMS) gives better water repellency. When cotton fabric was treated earlier with DCDMS, though water repellency property was enhanced, the fabric lost its strength due to hydrochloric acid [HCl] generated during the condensation reaction [8]. So, it is considered necessary to carry out the investigation using a suitable textile material, which precludes side reaction of HCl retaining the material unaffected. Therefore the experiments are carried out with polyester fabric.

2. Experimental

2.1 *Materials*

100% polyester fabric (120 ends/in., 92 picks/in., 96 g/m^2) was provided by M/s Spectrum Dyes and Chemicals Ltd (Surat, Gujarat, India).

2.2 *Method*

Similar method was adopted to treat the polyester fabrics with plasma and DCDMS, as in the case of cotton fabrics [8]. Characterization techniques like % weight gain, colour parameters, mechanical property and surface morphology studies were also accepted in a similar way.

3. Results and discussion

Figure 1a illustrates the % weight loss of polyester fabric due to the plasma exposure at optimized condition. From figure 1a, it can be observed that exposure of polyester fabric in plasma causes a continuous weight loss in its actual weight, which may be attributed due to the etching action and cleaning process. As the weight loss of polyester fabric after plasma exposure for 2 min is found less than 1% (which is negligible), it has been thought necessary to optimize this duration of plasma exposure for further study.

Figure 1b demonstrates the effect of prior exposure of polyester fabric in plasma followed by DCDMS treatment with those treated directly on the % weight gain of polyester fabric. From figure 1b, a continuous weight gain can be seen, which may be attributed to the formation of silane layers onto the polyester surface during treatment with increasing treatment time. It has also been evidenced that prior exposure of polyester fabrics in plasma results in more deposition of silane group onto the surface compared to those directly treated with DCDMS solution.

To assess the effect of DCDMS on the visual appearance of fabric, colour parameters of the untreated and treated polyester samples were measured [10]. From table 1, it can be clearly observed that treatment of DCDMS does not make any

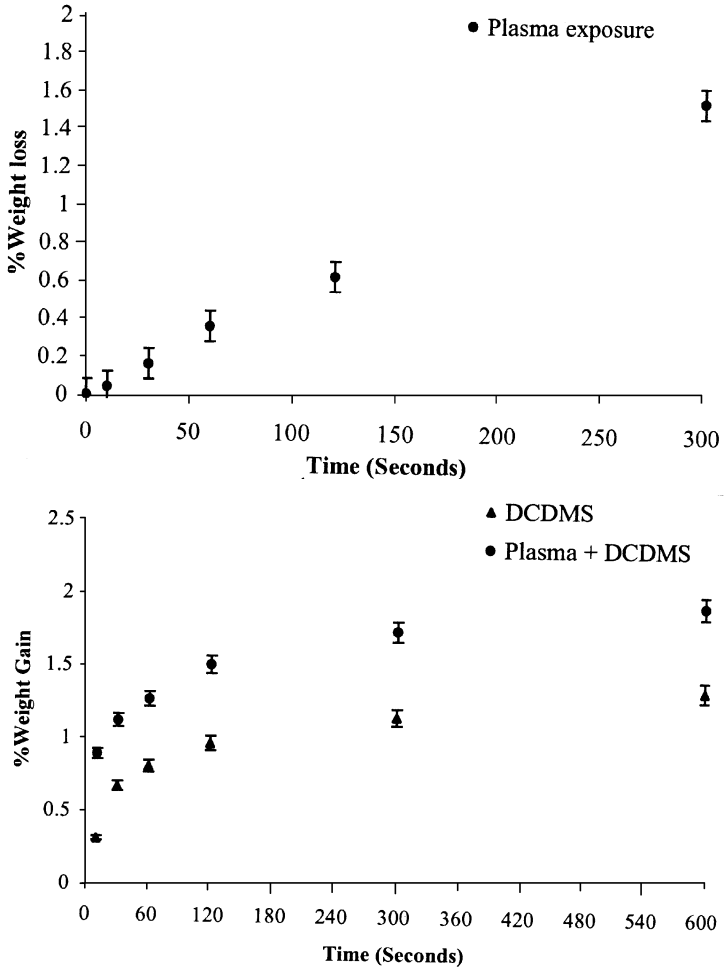

Figure 1. (**a**) Percentage weight loss of polyester fabric after plasma treatment. (**b**) Percentage weight change of polyester fabric treated with DCDMS.

difference on its visual appearance as the yellowness index (YI) and b^* values do not show any markable change, which is mainly due to the non-reaction of polyester fabric with HCl vapors, which are generated during the treatment of DCDMS solution and polyester fabric. This further encourages us to check the influence of treatment of DCDMS solution onto the bulk properties of the treated polyester fabric. From table 2, it can be seen that the bulk property of the polyester fabric is not altered much due to its treatment with DCDMS solution, which is mainly due to non-reaction of polyester fabric with liberated HCl vapors during immersion. Also, it can be evidenced from table 3 that prior exposures of plasma for shorter duration do show some improvement in bulk properties of polyester fabric treated with DCDMS solution. Figure 2 shows the scanning electron micrographs of both 2-min DCDMS treated and control polyester fabrics. From figure 2, it can

Table 1. Colour parameters of DCDMS-treated polyester fabric.

Treatment time	Colour parameters					
	L^*	a^*	b^*	C	h	YI
Control	92.23	0.06	2.31	2.31	88.62	4.57
10 s	92.57	−0.21	2.61	2.62	94.60	4.92
30 s	92.59	−0.27	2.81	2.82	95.56	5.25
1 min	92.36	−0.11	2.38	2.39	92.67	4.58
2 min	92.11	−0.09	2.36	2.37	92.11	4.56
5 min	92.16	−0.09	2.78	2.78	91.95	5.36
10 min	92.38	−0.14	2.51	2.51	93.20	4.79

Table 2. Mechanical properties of DCDMS-treated polyester fabric.

Treatment time	Load at break (g)	Elongation at break (%)	Tensile strength retained (%)
Control	465 ± 2	39	100.00
10 s	461 ± 3.8	37.3	99.14
30 s	460.5 ± 3.7	35.2	99.03
1 min	459.6 ± 2.9	32.6	98.84
2 min	461.5 ± 3.8	32.1	99.25
5 min	460.8 ± 4.1	31.6	99.10
10 min	453.9 ± 3.5	31.3	97.61

be observed that the deposition of DCDMS onto the polyester surface causes the change in its surface morphology and structure, which is mainly attributed to the formation of an additional layer of silane group onto its surface.

It has already been evidenced that formation of silane group on any textile material results in its water retardancy. Hence, it was thought necessary to check the water repellency behaviour of treated polyester fabric. For obtaining the wettabilities (or hydrophilicities) of untreated and modified polyester fabrics, a water drop test was applied according to the AATCC standard [9]. The fabric was washed in Roaches Pyrotec MB2 IR two-bath dyeing machine at 60°C for 30 min without using any soap or detergent, and then dried in air at room temperature. Similar experiment was set up for testing the absorbancy of modified polyester fabric as in case of modified cotton fabric [8]. It was found that the modified polyester fabric with prior exposure of plasma treated even for 10 s with DCDMS solution does not absorb the water droplets up to 1 h; whereas those fabrics treated directly with DCDMS solution do absorb the water droplets at around 50–55 min. Such samples were also washed up to 10 cycles, but no markable change in the modified property was observed. The modified property of water repellency behaviour of polyester fabric can be clearly seen in figure 3.

In order to investigate the effect of plasma treatment on the surface of the polyester fabric, ATR-IR study was carried out. Figure 4 demonstrates the ATR spectra of untreated and different processed polyester fabric.

Table 3. Mechanical properties of DCDMS-treated plasma exposed polyester fabric.

Treatment time	Load at break (g)	Elongation at break (%)	Tensile strength retained (%)
Control	465 ± 2	39	100.00
Plasma (2 min)	464 ± 2	38.6	99.78
10 s	469 ± 2	39.3	100.86
30 s	470.5 ± 2	39.8	101.18
1 min	467.5 ± 2	38.7	100.54
2 min	462 ± 2	37.6	99.35
5 min	461 ± 2	35.9	99.14
10 min	453 ± 2	33.3	97.42

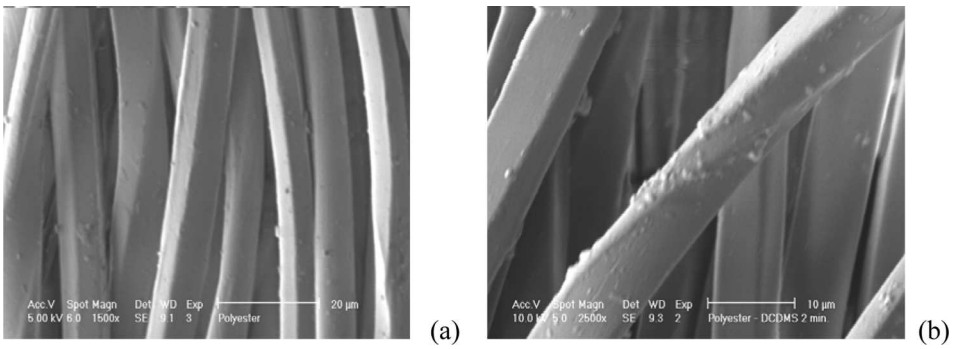

Figure 2. SEM micrograph of (**a**) untreated polyester fabric and (**b**) 2-min DCDMS treated polyester fabric.

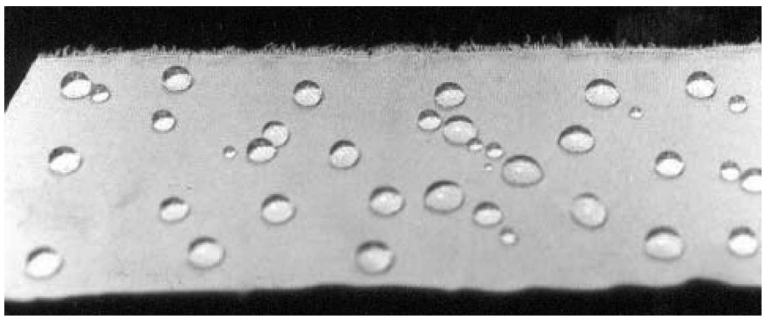

Figure 3. Photograph of 10-s DCDMS treated polyester fabric.

Table 4. Relative intensities of DCDMS treated polyester fabric.

Functional groups	Relative intensity	
	Polyester fabric treated with DCDMS	Plasma treated polyester fabric followed by DCDMS
CH_3, stretching vibration	0.2993 (at 2964.4 cm^{-1})	0.2340 (at 2963.3 cm^{-1})
C=O, stretching vibration	0.2067 (at 1713.7 cm^{-1})	0.1988 (at 1713.3 cm^{-1})
Si–CH_3-deformation vibration	0.5483 (at 1258.4 cm^{-1})	0.5827 (at 1258.8 cm^{-1})
Si–O linkage	0.8232 (at 1079.1 cm^{-1})	0.7713 (at 1084.5 cm^{-1})
Si–O–C	0.9853 (at 1020.1 cm^{-1})	0.8055 (at 1015.9 cm^{-1})
Si–C, stretching vibration	0.3131 (at 864.7 cm^{-1})	0.2479 (at 866.7 cm^{-1})
Si–Cl, stretching vibration	1.0000 (at 794.5 cm^{-1})	1.0000 (at 793.1 cm^{-1})

From figure 4, it can be seen that plasma exposure of polyester fabric does not cause any remarkable change in the spectrum as compared to untreated polyester fabric except for changes in the relative intensities of the stretching vibrations of the functional groups, which determines its various properties. But when the fabric is treated with DCDMS solution some new peaks can be seen when compared with the spectrum of control fabric. Similar observations can also be made in case of prior exposure of plasma before treatment.

In the sample treated with DCDMS solution, the absorption at 2964.4 cm^{-1} is due to the CH_3 stretching vibrations. The peak at 1713.7 cm^{-1} is due to the stretching vibration of C=O group. This can be seen by the reduction in the relative intensity of C=O group after the treatment of DCDMS solution. The peak at 1258.4 cm^{-1} is due to the Si–CH_3 deformation vibration. The shoulder at 1079.1 cm^{-1} is because of the Si–O linkage. The peaks at 1020.1, 864.7 and 794.5 cm^{-1} are due to Si–O–C, stretching vibration of Si–C and stretching vibration of Si–Cl group respectively. So in general, CH_3, Si–CH_3, Si–O, Si–O–C, Si–C and Si–Cl groups are formed onto the cotton fabric after DCDMS treatment. These are also the groups found when the fabrics were treated with plasma followed by immersing in DCDMS solution, only difference being the change in their relative intensities; which can also be evidenced from table 3.

4. Conclusion

From the present investigation, it can be concluded that polyester fabric can be modified suitably by treating with DCDMS solution so as to make it water repellant without loosing its original strength. The modified polyester fabrics do attain

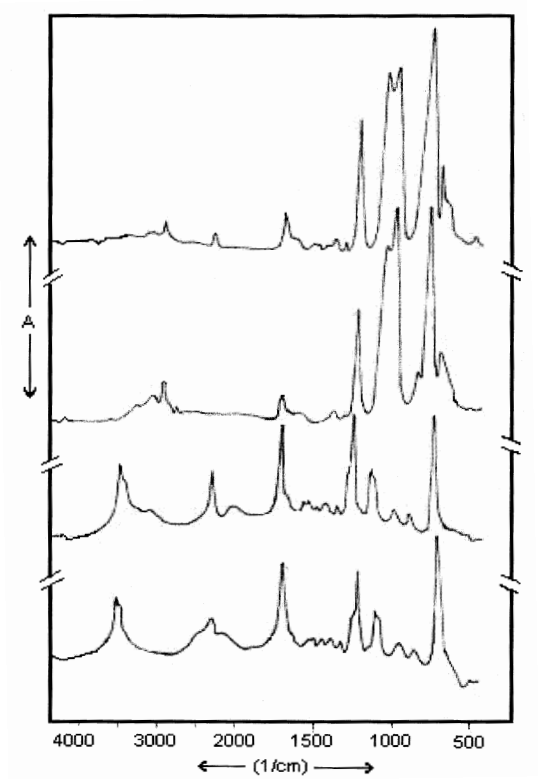

Figure 4. IR spectra of polyester fabric, (**a**) untreated; (**b**) 2-min plasma exposed; (**c**) 2-min DCDMS treated and (**d**) 2-min DCDMS treated after exposure of plasma for 2 min.

good water repellency even after washing with water for ten cycles. Prior exposure of plasma before treatment of DCDMS solution modifies the fabric leading to deposition of more and more silane groups making it water repellant as compared to those treated directly with DCDMS. For DCDMS treatment, the optimized duration of plasma exposure for polyester fabric is 2 min and 30 s. Large-scale feasibility of the process was not studied, and the present experiment have been carried out on a laboratory scale. If the cost factor of plasma device could be eliminated, this technology would be valid and useful for the textile finishing industry.

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