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WETTABILITY ANALYSIS OF PET FABRIC WITH O_2- AND NH_3- PLASMA TREATMENT

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ABSTRACT

Saha R (2012) Wettability analysis of PET fabric with O_2- and NH_3- plasma treatment. *Ins. Engg. Tech.* 2(3), 9-13.

Plasma modification plays an important role in wettability of PET fabric. Different PET fabrics show different behaviour in wetting after applying O_2- and NH_3- plasma and a Soil Release Polymer (SRP), which were observed and determined. For hydrophilic fabric, spreading rate and absorption rate are observed which based on dynamic contact angle. These are the wetting behaviour of PET fabric. Ammonia and Oxygen plasma are used to modify the PET fabric and impact of plasma and SRP on wettability were observed and studied.

Key words: *wettability, polyester fabric, plasma, soil release polymer (SRP)*

INTRODUCTION

Polyester has been one of the most popular, second to cotton as measured by production tonnage in recent years. The technical merits and commercial versatility of the fiber production system have led to successful product development and applications.

Polyester fibers as well as fabric have many desirable properties, including relatively high tenacity, low creep, good resistance to strain and deformation, high glass transition temperature (T_g), and good resistance to acids and oxidizing agents. These physical, mechanical, and chemical attributes make polyester excellent candidates not only for apparel and textile products but also for industrial and composite applications.

In other case, Polyester fibers retain little moisture and do not transport aqueous fluids. The hydrophobic nature of polyester fibers makes them difficult to hygienic use, difficult to dye and to finish in aqueous media. That is the one of the main drawback of polyester.

Plasma modification chemicaly change the surface behaviour to increase wettability. Soil release polymer (SRP) is also responsible for wetting phenomena.

Here, in this thesis observed different topographical parameters of supplied PET fabric. Different Plasma (NH_3, O_2) with different time and SRP are also induced to characterise the wettability, cleanability as well as topography and studied to establish correlation with each other.

Here plasma modification is done to observe the change in wetting behavior, before and after SRP treatment and the aim is to established correlation with each other.

MATERIALS

A polyester test fabric was used as substrate for this study. The fabric was supplied by Wfk-Testgewebe GmbH, Krefeld, Germany. The material was used as it received without any pretreatment. Different parameter of the test fabric is given in Table 1.

Table 1. Specifications of polyester fabric

Parameter	Value
Fineness (warp)	295 dtex
Fineness (weft)	295 dtex
Yarn density (warp)	270 +/- 5 yarn / dm
Yarn density (weft)	270 +/- 5 yarn / dm
Width	80 cm
Fabric weight	170 g/m^2
Weave	1 / 1 plain

EXPERIMENT

Plasma modification of PET fabric

The plasma treatment was done in a computer controlled customized MicroSys apparatus by Roth & Rau, Germany. The cylindrical vacuum chamber, made of stainless steel, has a diameter of 350 mm and a height of 350 mm. The base pressure obtained with a turbomolecular pump is $<10^{-7}$ mbar. A 'Micropole' mass spectrometer by Ferran, the United States, is used to monitor the residual gas. On the top of the chamber a 2.46 GHz electron cyclotron resonance (ECR) plasma source RR 160 by Roth & Rau with a diameter of 160 mm and a maximum power of 800 W is mounted. The process gas is introduced into the active volume of the plasma source via a gas flow control system. When the plasma source is on, the pressure is measured by a capacitive vacuum gauge. The sample were introduced by a load-lock-system and placed on a grounded aluminium holder near the centre of the chamber. The distance between the sample and the excitation volume of the plasma source is about 200 mm. For the plasma treatment the following parameters were applied respectively (Saha 2010): i) process gas NH_3 (99.999%, Messer Griesheim, Germany), flow 15 standard cubic centimeters per minute, pressure 3.6×10^{-3} mbar, effective microwave power 600 W and ii) process gas O_2 (99.95%, Messer Griesheim, Germany), flow 15 standard cubic centimeters per minute, pressure 3.6×10^{-3} mbar, effective microwave power 100 W.

Fabric characterization by dynamic contact angle measurements

The static contact angle measurement to characterize interactions between a liquid and a solid surface is not longer thought to be adequate in all cases. In many practical applications, the wetting phenomena of interest are ‘dynamic’ in nature, involving a moving wetting line at which equilibrium is never attained. The contact angle of a moving wetting line is generally called dynamic contact angle. An image sequence of the initial contact angle and dynamic changes of contact angle of a drop, its base, height and volume over time can be captured to monitor the interaction of the droplet spreading across or penetrating into the solid surface. In this thesis, dynamic contact angle measurements were carried out to characterize the wetting properties of fabrics (Badrul 2007).

Dynamic wetting measurements were carried out with a dynamic spreading, absorption and contact angle tester FibroDAT 1122 HighSpeed (Fibro System, Sweden) according to the sessile drop method to estimate the degree of hydrophobicity of fabrics with water.

The device is equipped with a high speed video camera which collects up to a 1000 images per second, and has some advantages compared to other commercially available instruments:

- checking the surface tension of liquids according to the pendant drop technique before wetting measurements;
- adjustment of specified drop volumes using a liquid delivery system;
- tuning the deposition parameters – distance between drop and surface, time difference between drop formation on the syringe tip and drop deposition on surface, intensity of a stroke of electromagnet to release the drop from the tip.

The high speed video camera is used to take all analysed images by integrated software. The drop profile is digitalized and approximated with a suitable function, as shown in (Fig. 1) by green circle. Finally, the contact angle is determined using a base line (blue line). The base line is found by the software automatically. Before measuring, the position of the yellow line (should be minimal) is adjusted against the base line depending on the irregularity of the surface. The more the irregularity of the surface, the higher should be the distance. The drop profile between the yellow and base line is calculated by a mathematical extrapolation process. For these reasons, the distance between yellow and base line should be kept as minimum as possible to reduce the chance of error.

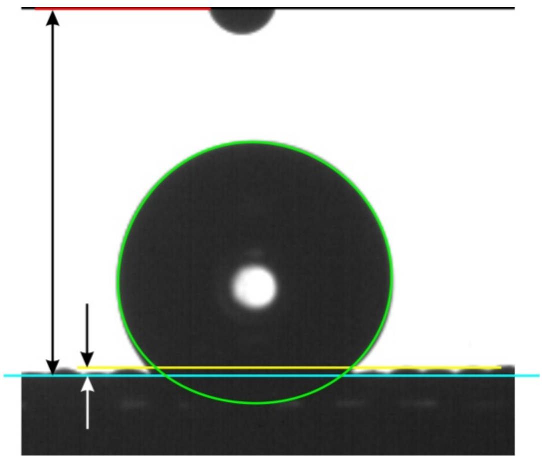

Fig. 1. Geometric parameters by dynamic contact angle measurements (Marmur 1992)

The strength of stroke should be kept as minimum as possible to avoid oscillation effects. As a drop with a strong stroke experiences a mechanical energy, which must be at first set free before its actual absorption takes place. Therefore, a drop deposited on a textile surface with stronger stroke takes longer time to be absorbed than that with weaker stroke (Calvimontes 2004).

In this thesis, drops of water of 5µl volume were applied onto the surface by a short stroke. The strength of the stroke was minimized to avoid the oscillation effects affecting the spreading process. After deposition, the drop is stabilised on the surface and reliable data are collected thereafter for 20 s. The measurements were done in a temperature and humidity controlled laboratory maintained 23°C ± 1°C and 40% ± 3%, respectively. For a water-fabric system an average contact angle of 20 single measurements was obtained.

On the basis of macroscopic water drop base changes, the wetting behaviour of the water drop can be divided into three different regimes (Fig. 2):

i) dynamic wetting, defined as growing of the drop diameter depending on time (also known as spreading), the quasi-static wetting, ii) here the drop diameter remains approximately constant and iii) penetration, which is marked by liquid drop absorption into fabrics depending on time.

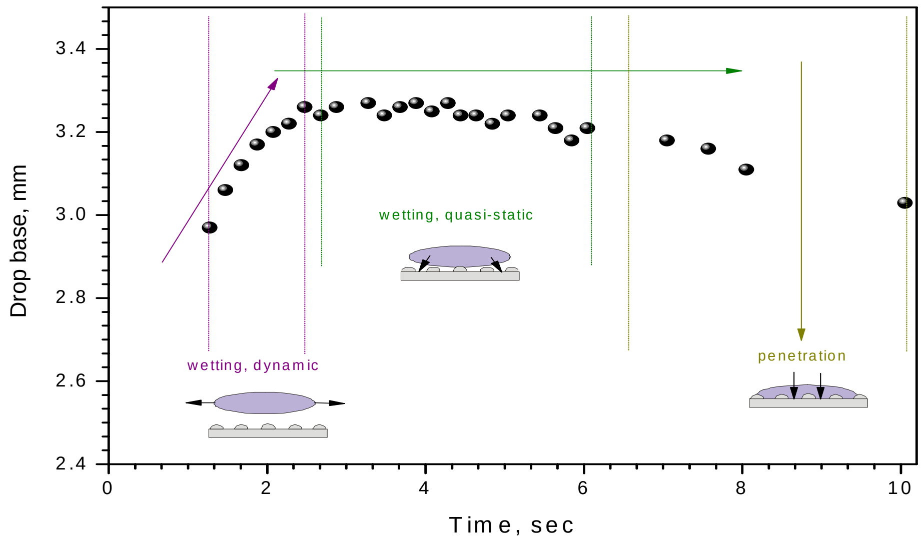

Fig. 2. Three different wetting regimes of tested PET surface

The contact angle of water in case of hydrophobic, spreading rate and absorption rate in case of hydrophilic were measured to evaluate the wettability of the fabrics.

RESULTS AND DISCUSSION

In this thesis PET fabrics were modified with NH_3- and O_2- plasma using different treatment durations and Soil Release Polymer (SRP) is used to impregnation.

FibroDAT 1100 dynamic contact angle tester (Fibro System, Sweden) was used for dynamic wetting measurements. Water drops of 5 µL volume were applied to the surface under investigation by a short stroke from an electromagnet. The strength of the stroke was minimized to avoid oscillation effects.

Wettability in case of original sample

Table 2. Wettability of origin fabric

SRP				Without SRP			
Spreading rate (mm/sec)		Absorption rate (µl/sec)		Spreading rate (mm/sec)		Absorption rate (µl/sec)	
Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
47.80	3.53	48.05	11.39	3.23	0.48	0.32	0.05

It is crearly found in Table 2 that after modification by Soil Release Polymer (SRP) spreading and absorption rate increased significantly but at the same time error percentage was also high.

Wettability in case of NH_3 plasma

Table 3. Wettability of NH_3 plasma modified fabric

Treated time (min)	SRP				Without SRP			
	Spreading rate (mm/sec)		Absorption rate (µl/sec)		Spreading rate (mm/sec)		Absorption rate (µl/sec)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2	4.68	1.13	0.61	0.68	1.12	0.57	0.02	0.01
5	71.95	4.63	10.71	4.82	2.01	0.39	0.23	0.05
10	70.05	9.94	48.43	6.35	2.55	0.42	0.59	0.20

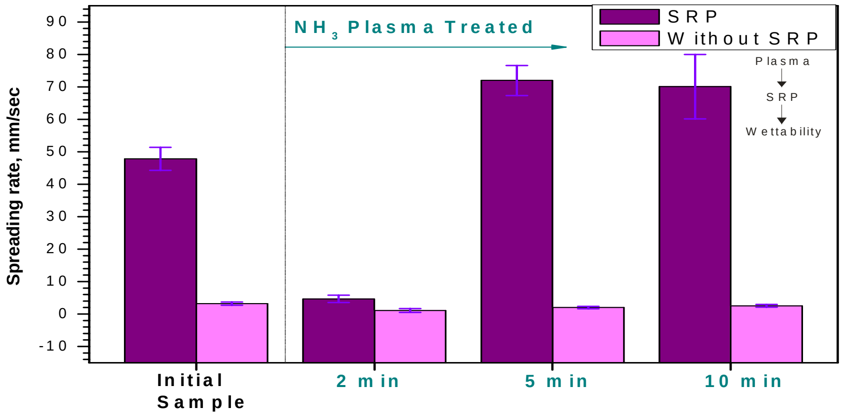

Fig. 3. Spreading rate of NH_3-plasma modified fabric

Before impregnation with SRP, measured spreading rate of a water drop on untreated fabric is 3.2 mm/sec. After impregnation this parameter increases up to 47.8 mm/sec (Fig. 3 and Table 3).

NH_3-plasma treatment practically does not change spreading rate. But impregnation of NH_3-plasma treated samples increases spreading rate up to approximately 70 mm/sec, if plasma duration treatment is at least of 5 minutes, according to experimental results.

According to water absorption rate measurements, untreated fabric absorbs water in a rate of 0.054 µL/sec, while after impregnation with SRP, this value increases to 48.0 µL/sec, as illustrated in Fig. 4 and Table 3. Modification with NH_3-plasma does not change significantly water absorption rate, but SRP-impregnation of NH_3-plasma treated fabrics increases water absorption as a function of plasma treatment duration, from 0.61 µL/sec for 2 min up to 48.4 µL/sec for 10 min treatment. Measured errors are proportional to the absorption value.

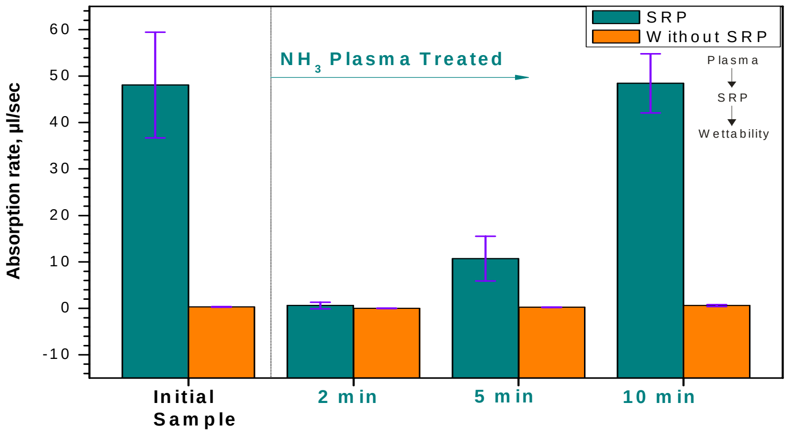

Fig. 4. Absorption rate of NH_3-plasma modified fabric

Wettability in case of O_2 plasma

Table 4. Wettability of O_2 plasma modified fabric

Treated time (sec)	SRP				Without SRP			
	Spreading rate (mm/sec)		Absorption rate (µl/sec)		Spreading rate (mm/sec)		Absorption rate (µl/sec)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
10	2.57	0.38	1.98	0.16	1.78	0.46	0.41	0.04
20	1.86	0.44	3.72	0.22	2.28	0.48	0.62	0.05
30	2.64	0.33	2.62	0.26	4.80	0.66	3.46	0.29

Interestingly, by O_2-plasma treated and O_2-plasma/impregnated fabrics, surface modification plays practically no effect on both dynamic parameters, spreading rate and absorption rate, according to Figs. 5 and 6, also in Table 4.

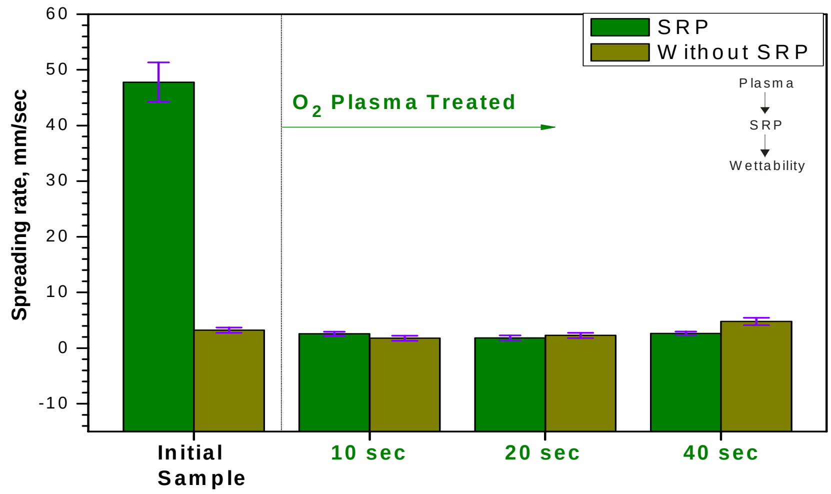

Fig. 5. Spreading rate of O_2 plasma modified fabric

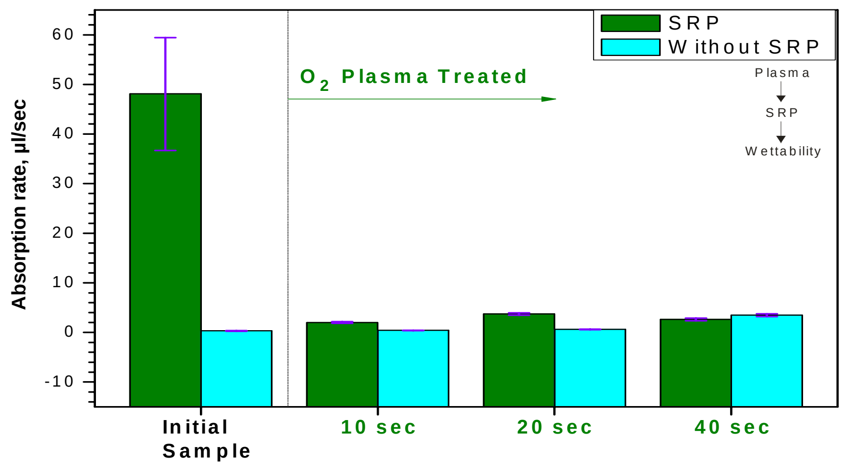

Fig. 6. Absorption rate of O_2 plasma modified fabric

Comparison study

After plasma modification, prominent increase of spreading and absorption rate was observed in NH_3-plasma than O_2-plasma, only after SRP impregnation. But in 'without SRP' samples there is no significant change in all cases i.e. O_2- and NH_3-plasma modification and without plasma modification. The O_2 plasma modification plays no role in spreading and absorption rate. There is a linear increase in absorption rate after SRP modification in case of NH_3 plasma modified fabric. However, in all cases, plasma treated and thermofixed, measurement errors are too big.

CONCLUSION

The ultimate object of this research is to verify if plasma treatment can improve the wettability of the posterior impregnation with SRP. Results show that NH_3- plasma irradiation time gives better result than O_2-plasma. SRP-impregnation on untreated fabric is much more effective than on plasma treated fabrics. In other words, untreated fabric is more sensible to the chemical effect of SRP than plasma modified ones. To know the hydrophilisation mechanism that explains this observation is a very interesting topic for future investigations.

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