Polish Journal of Chemical Technology, 16, 4, 21 — 27, 10.2478/pjct-2014-0064

Study on the improvement of hydrophilic character on polyvinylalcohol treated polyester fabric

Pitchai S.[1], Jeyakodi Moses J.[2], Swarna Natarajan[3]

[1] *PSG College of Technology, Part Time Scholar*
[2] *PSG College of Technology, Associate Professor, Department of Chemistry and Applied Chemistry*
[3] *PSG College of Technology, Assistant Professor, Department of Basic Sciences (Chemistry), Coimbatore – 641004, India*
[*] *Corresponding author: e-mail: jjmoses2k2@gmail.com*

Polyester fabric was treated with polyvinyl alcohol in alkaline medium. The moisture regain, water retention and wettability of the PVA treated polyester fabric were tested. The PVA treated PET fabric was dyed with disperse dye. The presence of PVA in the treated PET fabric was assessed by spot test. The treated fabric was also characterized by scanning electron microscope, FTIR and differential scanning calorimetry. The PVA treated polyester fabric showed improved hydrophilic character over intact and sodium hydroxide treated PET fabrics.

Keywords: Polyester fabric, PVA, SEM, FTIR, DSC, hydrophilic character.

INTRODUCTION

Polyethylene terephthalate (PET) commonly called as polyester is widely accepted as a textile material is due to its excellent physical and chemical properties. The hydrophobic nature of polyester material with a moisture regain of only 0.6–0.8% even at 100% relative humidity is a disadvantage when the material needs to be wettable, and the fibers do not absorb water as do natural fibers like cotton. The fabric worn next to skin should absorb perspiration and facilitate heat exchange with surroundings[1].

The conventional modification of PET fiber properties is through strong alkaline treatment under high processing temperature. Alkaline finishing of polyester fabric with sodium hydroxide changes fabric weight, strength[2, 3, 4, 5], wettability and aesthetics[6, 7]. Altering the surface characteristics of polyester is rather difficult due to its inactive chemical nature. But modifications of PET surface have been reported using various techniques such as; modification by surfactant–aided surface polymerization of methyl methacrylate[8], cyclodextrin based finishes for polyester fabric[9], surface grafting of polyester fiber with chitosan[10], lipase treatment of polyester fabric[11], magnetic activation of water in alkali treatment of polyester fiber[12], chemical introduction of sugars onto PET fabric using cyanuric chloride[13], hydrophilic treatment of polyester surface using TiO_2[14], atmospheric pressure plasma treatment of polyester fabric[15], protein immobilization on PET film[16], and application of silk sericin to polyester fabric[17].

In this research work, application of PVA on polyester fabric was carried out to modify the surface properties of base polymer to make it hydrophilic and to improve its comfort characteristics. Polyvinylalcohol has been used in textile industries[18], for a long period in many applications since it is a biodegradable polymer[19]. In this work, efforts have been taken to chemically bind PVA onto PET surface in alkaline medium for achieving permanent hydrophilic characteristics suitable for aesthetic values.

EXPERIMENTAL

Materials

The materials used in this study were as follows: Polyester fabric (continuous filament yarn, plain weave) with gsm 55; ends / inch 92 and picks / inch 80; Polyvinylalcohol $(C_2H_4O)_n$ with degree of polymerization, 1700–1800 (supplied by Loba Chemie Pvt Ltd, Mumbai, India), Glutaraldehyde (25%), fatty alcohol, ethylene oxide, and propylene oxide (supplied by Merck Specialities Pvt Ltd, India).

Other chemicals such as hydrochloric acid, sodium hydroxide, glacial acetic acid, magnesium chloride, sodium lauryl sulphate, sodium carbonate, iodine and boric acid mentioned elsewhere in this study were of analytical grade.

METHODS

Pretreatment of polyester fabric

Polyester fabric was immersed in 10 gpl HCl at 40°C and treated for one hour at the same temperature with material to liquor ratio 1:50, to get rid of the added impurities[9].

Treatment of sodium hydroxide on polyester fabric

The pretreated[9] PET fabrics were subjected to various concentrations of sodium hydroxide treatment at boil for one hour and two hours of treatment time.

Application of PVA onto polyester fabric

The pretreated PET fabric was immersed in 1N NaOH solution containing 1.5% by weight of PVA. It was kept in the bath at boil for one hour. Then the fabric was taken out and immersed in water at boiling temperature for 10 minutes and soaped[20] to remove the physically held PVA, washed and dried at room temperature.

In a separate bath similar treatment was carried out on polyester fabric without PVA. This sample was considered as control fabric.

Measurement of moisture regain in polyester fabric

Moisture regain of the polyester fabrics (intact, control, PVA treated) was determined as per the AATCC test

method 20A-1995, RA 24[21]. The moisture regain values were calculated from the following equation.

$$\text{Moisture regain} = \frac{(\text{weight of the conditioned fabric} - \text{weight of dried fabric}) \times 100}{\text{weight of dried fabric}}$$

Determination of water retention in polyester fabric

Absorptive capacity of polyester fabrics was measured by standard AATCC 21-1978 test method[22].

Measurement of wettability of polyester fabric

Wettability is the time taken for a water drop to penetrate into the polyester material. The wettability of PET fabrics was determined as per AATCC test method 79[23].

Measurement of water contact angle on polyester fabric

Water contact angle was measured on the polyester fabrics (intact, control and PVA treated) using Contact Angle Measuring System (model Phoenix 300 Plus, M/s Surface Electro Optics Co, Ltd, Korea). Drops of water (volume 8.0 μl) were placed on the fabric samples using a microsyringe. The measurements were taken immediately after placing the water drop and the variations followed for 10 minutes.

Identification of PVA in polyester fabric

The polyester fabrics were tested for the presence of PVA. The fabric samples were spotted with a drop of reagent A (boric acid) and a drop of reagent B (iodine solution). Photographs were taken after 5 minutes. Polyvinylalcohol reacts with boric acid and iodine to form a blue colour[24].

Dyeing of polyester fabric

The polyester fabrics were dyed using 0.5% (owf) dianix navy S2G (disperse dye) and 1g/l dispersing agent in a HTHP dyeing machine (Ahiba Polymat). The dyeing was carried out at temperature 130°C and at pH 5 (adjusted by acetic acid). The dyed samples were washed with hot water, soaped and dried[25].

Colour intensities of the dyed PET fabrics were measured using spectrophotometer (model: Premier colour scan ss 5000 A) within the range of 400–700 nm. Reflectance values were measured and the relative colour strength (K/S) was calculated using Kubelka Monk equation. (K/S) defines a relationship between spectral reflectance I of sample and its absorption (K) and scattering (S) characteristics. $K/S = \{(1-R)^2/2R\}$.

SEM analysis of polyester fabric

The surface morphology of polyester fabrics (intact, control and PVA treated) was observed in SEM (JOEL JSM-6360 model microscope, Japan)[26].

Fourier Transform Infrared (FTIR) study of polyester fabric

The ATR-FTIR measurements were carried out on polyester fabrics (intact, control and PVA treated) using an infrared spectrophotometer (Thermoscientific Nicolet is10)[27]. Attenuated total reflectance (ATR) spectra were recorded at a resolution of 4 cm^{-1} and accumulation of 32 scans.

Differential Scanning Calorimetry study on polyester fabric

The DSC for intact, control and PVA treated fabrics was carried out using Pyris 6 DSC thermal analyzer. The rate of heating was adjusted at 10°C/min. DSC traces were recorded from 25°C to 400°C under nitrogen atmosphere[28].

RESULTS AND DISCUSSION

Many trials were carried out on polyester fabric using sodium hydroxide alone and with PVA in different concentrations, time and temperature. The weight loss from the polyester fabric and characteristic changes were considered. Based on these, the optimized conditions for application on the polyester fabric using sodium hydroxide and PVA were fixed. The data are presented in the Tables 1, 2, 3 and 4; and the effect is shown in Figure 1 to Figure 12.

Effect of PVA treatment in PET fabrics

To confirm the concentration of PVA (1.5%), the PET fabrics were treated in alkaline medium (1.0 N NaOH) with different concentration of PVA (0.5%, 1.0%, 1.5% and 2.0%) for 60 minutes at boil. The moisture regain, water retention and wettability of the PET fabrics were assessed. The data of the output of these treatments are given in Table 1. As the concentration of PVA increases from 0.5 to 2.0% the moisture regain (0.62 to 1.11%) and water retention (128 to 145%) values are also increased correspondingly whereas the respective time of wettability is reduced (214 sec to 184 sec) in the PET fabrics treated in alkaline medium. From Table 1 it is evident that the results of moisture regain, water retention and wettability are good on the PET fabric treated with 1.5% PVA in 1.0 N sodium hydroxide solution for 60 minutes at boil. This may be taken as an indication of the fact that the end hydroxyl groups of PVA binds onto PET surface via base catalysed transesterification reaction.

Water contact angle in polyester fabric

Water contact angle of intact, control and PVA treated PET fabrics are given in Table 2. When a water droplet is placed on these fabrics, it almost spreads completely within 5 minutes in PVA treated PET fabric compared to the control and intact PET fabric in that even after 10 minutes the water droplet is not spread fully. PVA treated PET fabric shows a static water contact angle 67.31° (<90°) indicating that the fabric is wetted by water easily[29]. The control and intact PET fabric show static water contact values > 90° , which reveals their hydrophobic character. This result shows the enhanced hydrophilic character of PVA treated fabric.

Spot test in the polyester fabric

Based on the above results (Table 1 and Table 2) the optimum condition for the treatment on PET fabrics is 1.0 N sodium hydroxide, 1.5% PVA for 60 minutes at

Table 1. Effect of PVA treatment in PET fabrics

PET fabrics	Sodium hydroxide [N]	Treatment time [mi]	PVA [%w/v]	Moisture regain [%]	Water retention [%]	Wettability [sec]
1	1.0	60	0	0.40	115	>400
2	1.0	60	0.5	0.62	128	214
3	1.0	60	1.0	0.87	138	192
4	1.0	60	1.5	1.05	144	188
5	1.0	60	2.0	1.11	145	184

Table 2. Water contact angle of the PET fabric

Time [minutes]	Water contact angle [°] of the PET fabric		
	Untreated	Control	PVA treated
0	124.24	116.75	67.31
1	119.56	107.52	56.79
2	113.88	100.99	53.45
3	104.24	97.15	33.86
4	93.05	94.80	<10
6	80.30	83.34	–
8	55.56	73.95	–
10	33.91	59.13	–

boil. The untreated PET fabric is considered as intact and the 1.0 N sodium hydroxide treated PET fabric is considered as control. The PET fabrics (intact, sodium hydroxide treated and PVA treated) were tested for the presence of PVA. Photographs of these fabrics (intact, sodium hydroxide treated and PVA treated) subjected to spot tests are given in Figures 1, 2, and 3 respectively. When the PET fabrics were spotted with reagents blue colour was developed in the PVA treated sample, and no colour was obtained on the control and intact PET fabrics. The development of blue colour in the PVA treated PET fabrics confirms the permanent nature of attachment of PVA to PET in alkaline medium. Intact and control fabric did not develop colour confirming the absence of PVA.

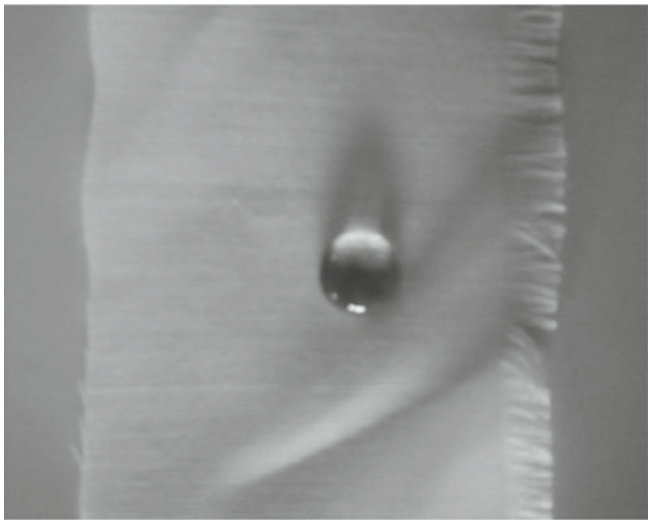

Figure 1. Spot test on untreated PET fabric

Dyeability of polyester fabrics

The optimized PET fabric samples such as; intact, control and PVA(1.5%) treated were dyed using dianix navy S2G (disperse dye) and the K/S values are given in Table 3. From the Table 3 it is evident that the sodium hydroxide treated control fabric does not show much increase in K/S value compared to the intact PET fabric. This is in agreement with previous reported studies that the dye uptake of polyester fabric with disperse dye does not increase by alkali treatment[30].

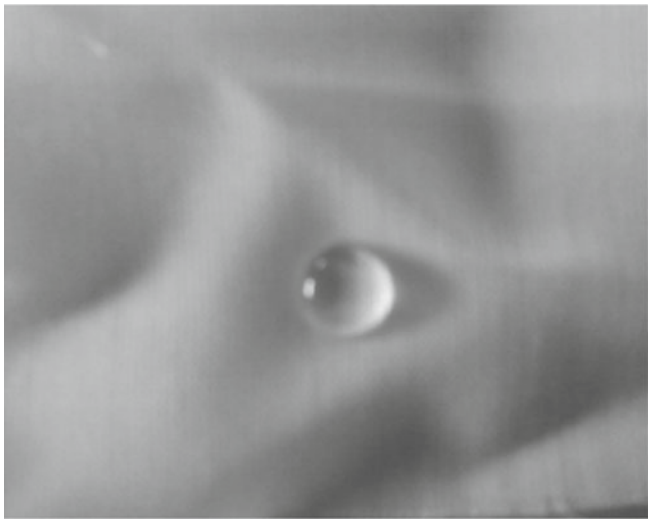

Figure 2. Spot test on control PET fabric

Figure 3. Spot test on PVA treated PET fabric

Of the three samples PVA treated PET fabric showed a highest K/S value indicating a high dye uptake. The dyeability of PET fabric with disperse dyes is believed to be independent of surface functional groups[31]. The increase in dye uptake of PVA treated PET fabric may be due to the decrease in crystallinity of the fabric leads to the increase in wettability which favours for easy dye penetration in the fiber substrate.

Table 3. K/S value of the disperse dyed PET fabric

S. No.	PET fabric	K/S value (610 nm)
1	Untreated	0.459
2	Control	0.464
3	PVA treated	0.677

Spectral investigation of polyester fabric

SEM analysis

The surface morphology of intact, control and PVA treated PET fabrics is shown in Figures 4, 5, and 6 re-

spectively. Figure 6 shows clearly the uniform presence of PVA on the surface of PET fabric and did not fill up the interstices[32]. SEM photograph of sodium hydroxide treated control fabric (Fig. 5) shows that sodium hydroxide served to influence the swelling of PET fabric than that of intact fabric (Fig. 4).

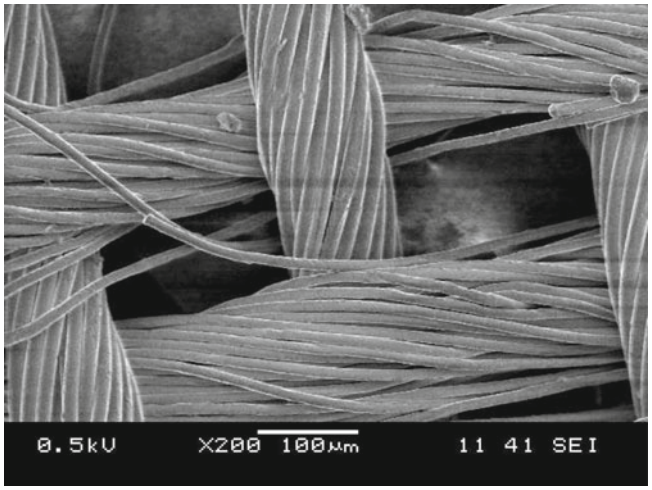

Figure 4. SEM photograph of intact PET fabric

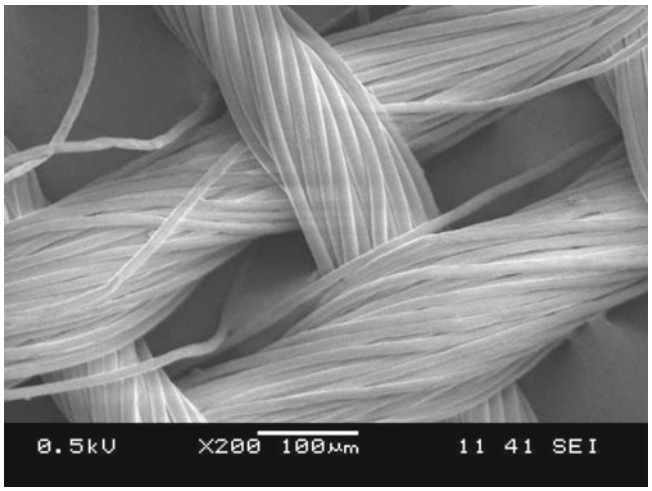

Figure 5. SEM photograph of control PET fabric

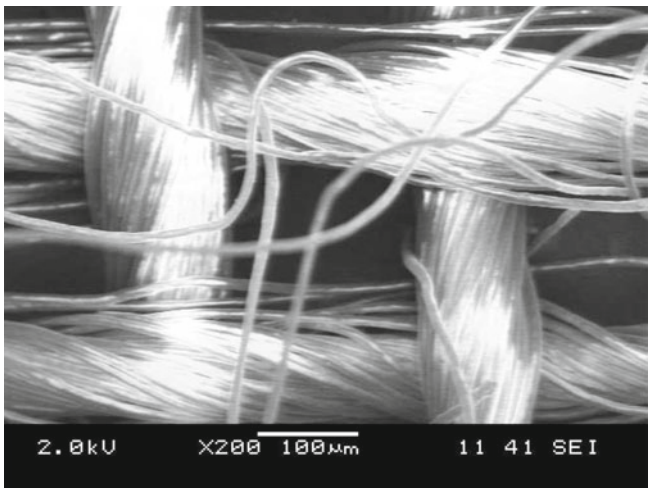

Figure 6. SEM photograph of PVA treated PET fabric

FTIR analysis of polyester fabric

The ATR-FTIR spectra of intact, control and PVA treated PET fabrics were analyzed as presented in Figures 7, 8, and 9 respectively. The high peaks from 1700 cm^{-1} to 600 cm^{-1} indicate the original signals, such as characteristic spectra of stretching vibration band of C=O at 1730 cm^{-1} and C-O-C stretching vibration band at 1097 cm^{-1} and 1240 cm^{-1}. All these peaks confirm the existence of ester linkage[33]. Sodium hydroxide treated control fabric shows an additional peak at 2359 cm^{-1}. This is attributed to carboxylic group (–COOH), introduced on the surface due to hydrolysis of the ester linkage. The PVA treated PET fabric shows a broad band in the region 3435 cm^{-1} which shows the presence of hydroxyl groups and the peak at 2359 cm^{-1} is absent in the PVA treated fabric. This confirms the adsorption of PVA onto the PET surface. This can be due to attachment of PVA on PET fabric surface by base catalyzed transesterification reaction.

Thermal Analysis of polyester fabric

Thermo-physical properties of the PET fabric samples were characterized using differential scanning calorime-

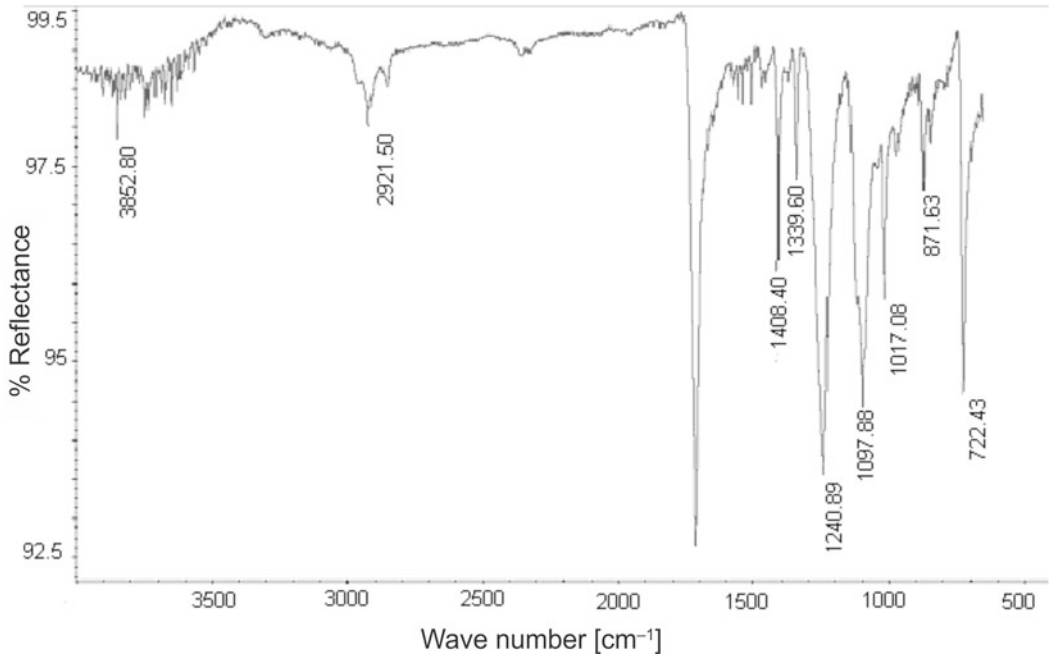

Figure 7. ATR-FTIR spectra of intact PET fabric

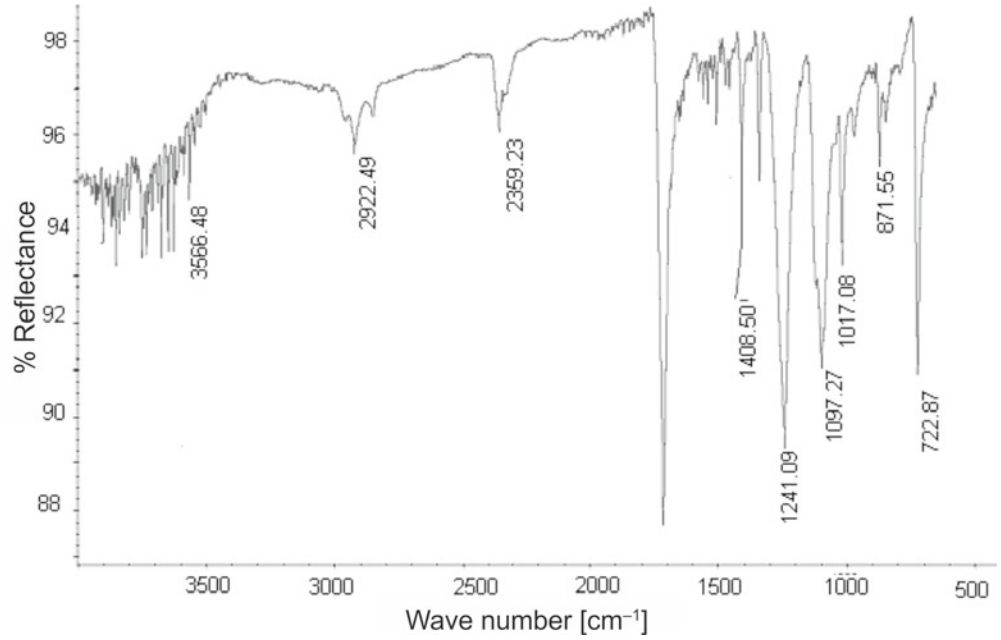

Figure 8. ATR-FTIR spectra of control PET fabric

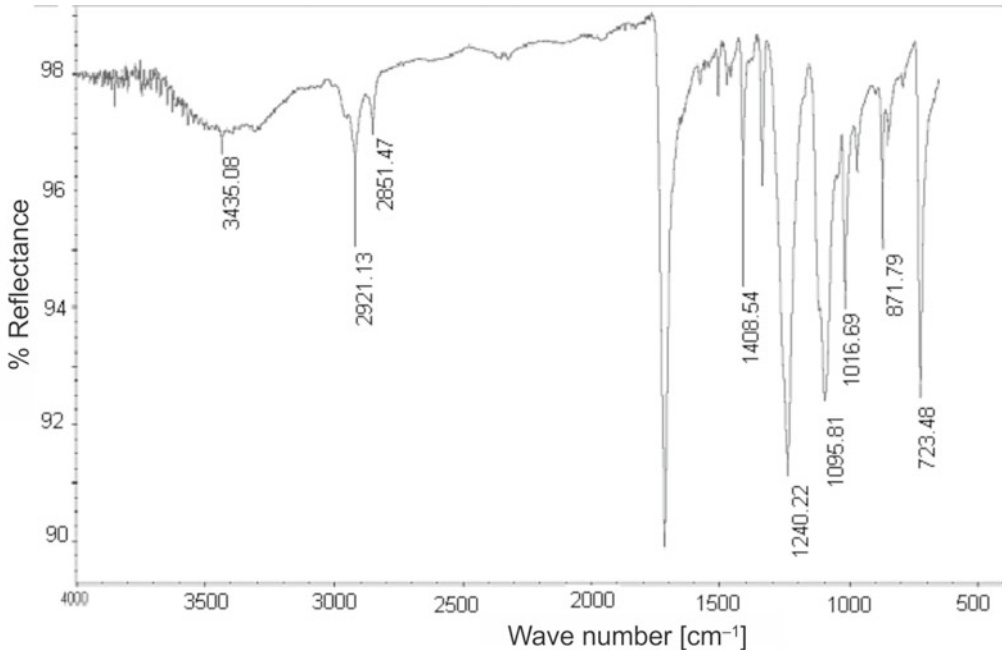

Figure 9. ATR-FTIR spectra of PVA treated PET fabric

ter[34]. Thermal curves of intact, control and PVA treated PET fabrics are given in Figure 10 (a, b, c). The data are given in Table 4. Melting temperature of PVA attached PET fabric exhibited a drop of 7°C compared to intact fabric. The average heat of fusion of PVA treated fabric was 29.617 J/g where as that of intact fabric was 81.327 J/g.

Table 4. Roughness parameters (R_a, R_z) for alumina plates (mechanical surface analyzer)

S.No.	PET fabric	Temperature peak [°C]	ΔH [J/g]
1	Untreated	254.04	81.327
2	Control	253.69	43.592
3	PVA treated	247.07	29.617

CONCLUSION

The wetting behavior of PVA treated PET fabric was increased considerably due to the good linkage between PET and PVA. Increased moisture regain, water retention, and wettability of PVA treated PET fabric highlight the improved hydrophilic behaviour of the PET fabric. The water contact angle of PVA treated PET fabric was much less than the intact and control PET fabric which reveals its hydrophilic character. The presence of PVA in the PET fabric after its application was confirmed by spot test and facilitating the fabric for the reactive process. This behavior leads to exhibit increased dye uptake with disperse dye in PVA treated PET fabric. The presence of PVA and the hydroxyl groups is also confirmed by SEM and FTIR studies. DSC traces of PVA attached PET

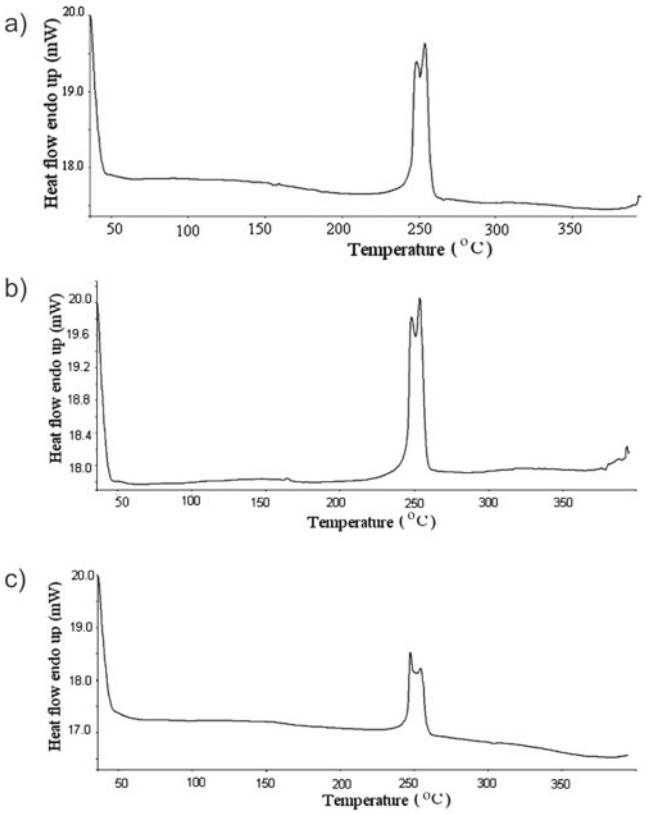

Figure 10. DSC traces of PET fabrics a) Intact PET fabric, b) Control PET fabric c) PVA treated PET fabric

fabric exhibited a lower melting temperature and lesser value of heat of fusion compared to intact PET fabric.

ACKNOWLEDGMENT

The authors kindly express their gratitude to Dr.R.Rudramurthy, Principal and the Head, Department of Chemistry and Applied Chemistry, PSG College of Technology, Coimbatore 641004 for granting permission and support in publishing this research article.

LITERATURE CITED

1. Billmeyer, F.W. (1994). *Textbook of Polymer Science* (John Wiley & Sons (Asia) Pte. Ltd, Singapore).

2. Gorrofa, A.A.M. (1980). Caustic Treatment of Polyester Filament fabrics. *Textile Chem Color.* 12,83/33-87/37.

3. Houser, K.D. (1983). Caustic reduction of polyester fabrics. *Textile Chem. Color.* 15, 70/37-72/39.

4. Ellison, M.S., Fisher, L.D., Alger, K.W. & Zeronian, S.H. (1982). Physical properties of polyester fibers degraded by aminolysis and by alkalin hydrolysis. *J. Appl. Polym. Sci.* 27(1), 247–257. DOI: 10.1002/app.1982.070270126.

5. Jayshree, Dave, Raj Kumar & Srivastava, H.C. (1987). Studies on modification of polyester fabrics I: Alkaline hydrolysis. *J. Appl. Polym. Sci.* 33(2), 455–477. DOI: 10.1002/app.1987.070330215.

6. Erin Murphy Sanders & Haig Zeronian, S. (1982). An analysis of the moisture-related properties of hydrolyzed polyester. *J. Appl. Polym. Sci.* 27(11), 4477–4491. DOI: 10.1002/app.1982.070271135.

7. Olson, L.M. & Wentz, M. (1984). Moisture related properties of hydrolysed polyester fabrics. *Tex. Chem. Color.* 16, 48/35-54/41.

8. Ampornphan Siriviriyanun, Edgar A. O'Rear & Nantaya Yanumet. (2007). Modification of polyester fabric properties by surfactant-aided surface polymerization. *J. Appl. Polym. Sci.* 103(6), 4059–4064. DOI: 10.1002/app.25451.

9. Abdel-Halim, E.S., Abdel-Mohdy, F.A., Salem S. Al--Deyab & Mohamed H. El-Newehy. (2010). Chitosan and monochlorotriazinyl-β-cyclodextrin finishes improve antistatic properties of cotton/polyester blend and polyester fabrics. *J. Carbohyd. Polym.* 82(1), 202–208, 2010.

10. Hu, S.G., Jou, C.H. & Yang, M.C. (2002). Surface grafting of polyester fiber with chitosan and the antibacterial activity of pathogenic bacteria. *J. Appl. Polym. Sci.* 86(12), 2977–2983. DOI: 10.1002/app.11261.

11. Hye Rim Kim & Wha Soon So (2006). Lipase treatment of polyester fabrics. *Fibers Polym.* 7(4), 339–343. DOI: 10.1007/BF02875764.

12. Knovalova, M.V. (2005). Magnetic activation of water in alkali treatment of polyester fiber materials. *Fibre Chem.* 37(2), 93–96. DOI: 10.1007/s10692-005-0061-1.

13. Ohe, T., Yoshimura, Y., Abe, I., Ikeda, M. & Shibutani, Y. (2007). Chemical Introduction of Sugars onto PET Fabrics Using Diamine and Cyanuric Chloride. *Tex. Res. J.* 77(3), 131–137.

14. Sawada, K., Sugimoto, M., Ueda, M. & Chan Hun Park. (2003). Hydrophilic Treatment of Polyester Surfaces Using TiO_2 Photocatalytic Reactions, *Tex. Res. J.* 73(9), 819–822.

15. Simor, M., Rahel', J., Cernak, M., Imahori, Y., Stefecka, M. & Kando, M. (2003). Atmospheric-pressure plasma treatment of polyester nonwoven fabrics for electroless plating, *Surf. Coat. Tech.* 172(1), 1–6. DOI:10.1016/S0257-8972(03)00313-X.

16. Drobota, M., Aflori, M. & Barboiu, V. (2010). Protein Immobilization on Poly(ethylene terephthalate) films modified by plasma and chemical treatments. *Dig. J. Nanomater. Bios.* 5(1), 35–42. DOI: 10.1109/TPS.2005.845372.

17. Gulrajani, M.L., Brahma, K.P., Senthil Kumar, P. & Roli Purwar. (2008). Application of silk sericin to polyester fabric. *J. Appl. Polym. Sci.* 109(1), 314–321. DOI: 10.1002/app.28061.

18. Tomasino, C. (1992). *Chemistry and Technology of Fabric Preparation and Finishing;* Department of Textile Engineering, Chem. Sci. Coll. Text., North Carolina State University.

19. Emo Chiellini, Andrea Corti, Salvatore D'Antone, Roberto Solaro. (2003). Biodegradation of poly (vinyl alcohol) based materials, *Progr. Polym. Sci.* 28(6), 963–1014. http://dx.doi.org/10.1016/S0079-6700(02)00149-1.

20. Cook, J.G. (2005). *Handbook of Textile Fibres,vol II-Man Made Fibres* (Woodhead Publishing Limited,Cambridge,England).

21. AATCC. (1996). Technical Manual,American Association of Textile Chemists and Colorists, Research Triangle Park,N.C.

22. AATCC. (1979). Technical Manual,Vol 55, American Association of Textile Chemists and Colorists, Research Triangle Park, N.C.

23. AATCC. (1991). Technical Manual, Vol 66, American Association of Textile Chemists and Colorists, Research Triangle Park,N.C.

24. Zeronian, S.H. (1999). *Analytical Methods for a Textile Laboratory,* American Association of Textile Chemists and Colorists, Research Triangle Park, N.C.

25. Oktem, T., Seventekin, N., Ayhan, H. & Piskin, E. (2000). Modification of polyester and polyamide fabrics by different in situ plasma polymerization methods. Turk. *J. Chem.* 24, 275. ISSN: 13000527

26. Hearle, J.W.S. (1972). *Use of the Scanning Electron Microscope* (Pergamon Press, Oxford).

27. Sawyer, D.T., Heineman, W.R. & Beebe, J.M. (1984). *Chemistry Experiments for Instrumental Methods* (John Wiley & Sons,USA).

28. Gowariker, V.R., Viswanathan, N.V. & Sreedhar. (2008). *J. Polym. Sci.* (New Age International, New Delhi).

29. Shaw, D.J. (1970). *Introduction to Colloid and Surface Chemistry* (Butterworth & Co, London).

30. Anthony, J., Monte-Bovi, John & Sciarra, J. (1961). **S**tudy of the polyvinyl Alcohol-borate-iodine complex II. Test papers. *J. Pharmac. Sci.* 50(3), 198–200. DOI: 10.1002/jps.2600500304.

31. Konovalova, M.V. & Rabaeva, Yu.M. (2007). Surface modification and dyeing of polyester fibres using magnetically activated aqueous solutions. *Fibre Chemistry.* 39(4), 318–321. DOI: 10.1007/s10692-007-0070-3.

32. Joseph, R., Shelma, R., Rajeev, A. & Muraleedharan, C.V. (2009). Characterization of surface modified polyester fabric, *J. Mater. Sci.: Mater. Medic.* 20, 153–159. http://www.springerlink.com/content/m577m7253k2w0564/

33. Xueliang Xiao, Fang Chen, Qufu Wei & Ning Wu. (2009). Surface modification of polyester nonwoven fabrics by Al_2O_3 sol–gel coating. *J. Coat. Technol. Res.* 6(4), 537–541. DOI:10.1007/s11998-008-9157-x.

34. ASTM Standard D3417-99. (1998). (ASTM, Philadephia,PA).