

Conductive polyaniline–polythiophene/poly(ethylene terephthalate) composite fiber: Effects of pH and washing processes on surface resistivity

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ABSTRACT: A conductive polyaniline (PAn)–polythiophene (PTh)/poly(ethylene terephthalate) (PET) composite fiber was prepared by polymerization of aniline and thiophene in the presence of PET fibers in an organic medium with FeCl_3 . The effects of polymerization conditions, such as polymerization medium, mol ratios of aniline/thiophene and FeCl_3 /aniline–thiophene as well as polymerization temperature and time, were investigated on PAn–PTh content (%) and surface resistivity of the composite. The composite with the lowest surface resistivity ($1.30 \text{ M}\Omega/\text{cm}^2$) was obtained by polymerization of aniline and thiophene (1/3 mol ratio) in acetonitrile/chloroform (1/5 volume ratio) at 20°C . The surface resistivity of the PAn–PTh/PET composite containing 4.8% PAn–PTh was increased from $1.9 \text{ M}\Omega/\text{cm}^2$ to $270 \text{ M}\Omega/\text{cm}^2$ at pH 11. The washing durability of the composites was determined with domestic and commercial laundering processes by monitoring the surface resistivity and morphology. The composite was also characterized with FTIR, TGA, elemental analysis, optic microscope and SEM techniques. © 2015 Wiley Periodicals, Inc. *J. Appl. Polym. Sci.* **2015**, *132*, 41979.

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INTRODUCTION

Conductive composites prepared by deposition of conductive polymers on fibers or fabrics could have superior electrical, thermal, and mechanical properties according to their components.^{1–3} Moreover, these types of composites have attracted the attention of researchers due to them having potential applications in antistatic and electromagnetic interference shielding,^{4,5} electrochromic⁶ and heating devices.⁷ In the preparation of conductive textile composites, polyaniline (PAn), polythiophene (PTh) and polypyrrole have been the most commonly used polymers among other conjugated polymers.^{7–9} In the preparation of a conductive polymer/fiber composite, both PAn and PTh polymers are preferred due to them having superior properties. PAn shows desired properties such as high conductivity, better environmental stability and ease of synthesis.^{10,11} However, the conductivity of PAn is adversely affected in solutions where the pH is over 4.¹² PTh has optical and electrical properties that offer better luminescence, electrochromism and photoconductivity.^{13,14} Moreover, the conductivity of PTh containing composites is more stable with respect to various environmental conditions such as washing processes.¹⁵ In the literature, there have been various studies reporting the usage of both PAn and PTh polymers for various purposes by electrochemical copolymerization of aniline and thiophene but their

composites with textile materials have not been prepared by chemical oxidative polymerization.^{16,17}

The fiber component of the composite, poly(ethylene terephthalate) (PET), is one of the most preferred polymers for use as a textile material due to it being cheap and showing high mechanical properties. However, it has some disadvantages, such as low hygroscopicity and static charge accumulation.¹⁸ These drawbacks related to PET fibers can be overcome by coating with or grafting on hydrophilic polymers and preparing its composites with conductive materials.^{15,19,20}

We aimed to prepare a conductive PAn–PTh/PET composite fiber and thus, combine the good properties of the composite components in a material by polymerization of aniline and thiophene in an organic medium with FeCl_3 oxidant in the presence of PET fibers. To the best of our knowledge, there has been only one study reported in the literature related to the coating of a textile with two different conductive polymer mixtures.²¹ In this reported study, polypyrrole and PTh mixtures were coated on PET fabric with FeCl_3 oxidant. Then, depending on the voltage applied to the composite, the changes in surface temperature, current passed from the composite, tensile strength and the surface resistivity were investigated.²¹ In our study, the changes in conductive polymer content (%) and surface

resistivity of PAN–PTh/PET composite fiber with polymerization conditions were investigated. Depending on the pH changes as well as the domestic and commercial laundering processes, the changes in the surface resistivity of the composite were also monitored.

EXPERIMENTAL

Materials

PET fibers (30 filaments, 110 Dtex) were obtained from ADVANSA-SASA Co. (Adana, Turkey) and used in the experiments after washing with acetone for 3 hours in Soxhlet for the purpose of cleaning. Aniline (Merck) and thiophene (Sigma-Aldrich) monomers were purified by vacuum distillation prior to use. The other chemicals such as acetonitrile, chloroform, dichloromethane, tetrachloroethylene (C₂Cl₄) supplied from Merck as well as HCl (37%), NH₄OH (5%) and anhydrous ferric (III) chloride (FeCl₃) (97%) supplied from Sigma-Aldrich were used as received.

Preparation of Conductive PAN–PTh/PET Composite Fiber

The PET fiber samples (0.200 ± 0.001g) became swollen when kept in dichloromethane at a boiling temperature for two hours, and they were used in the polymerization. Firstly, certain mol ratios of aniline and thiophene monomers were added to a fiber sample in a 50 mL of polymerization tube, and then the polymerization was initiated by adding a certain concentration of FeCl₃ solution into the mixture of acetonitrile and chloroform. At the end of the polymerization time, the composite fiber was taken from the mixture and washed with methanol, distilled water and 0.5M HCl solution, in order to remove the monomer, the oxidant, and enable redoping, respectively. After drying in a vacuum oven at 50°C, the sample was weighed and the conductive polymer content of the composite (PAN–PTh content, %) was calculated according to eq. (1):

$$\text{PAN–PTh content, \%} = \frac{m_c - m_f}{m_f} \times 100 \quad (1)$$

where m_f and m_c correspond to the PET fiber and composite fiber weights, respectively.

Characterization

In the measurements of the surface resistivity of the composite fibers, pellet samples were prepared under a 7 kN load, and they had a thickness of 2 mm and diameter of 1.3 cm. The measurements of low or high surface resistivity were performed using a two probe method with a Thurlby 1503 digital multimeter and Keithley 6517A. The averages of 10 measurements were taken from different points on the samples and given as the results. The surface resistivity of a pure PET fiber used in the study was $2 \times 10^{13} \Omega/\text{cm}^2$. The quantitative analysis of C, H, N and S elements in the samples were made with an Elemental Vario Micro Cube Elemental Analysis instrument. The FTIR spectra were recorded on a Mattson-1000 FTIR spectrometry as KBr pellets. The thermal behaviors of the samples were investigated with a Shimadzu DTA-60H Thermal Analyzer under a nitrogen atmosphere with a 10 mL/min flow rate and 10°C/min heating rate. The micrographs were taken with a Quanta 400F Field Emission SEM instrument using Au-Pd coated samples. The cross sections of fiber samples were prepared by cutting

Table I. The Changes in PAN–PTh Content (%) and Surface Resistivity of Composite Fiber with Solvent Types and Solvent Mixtures

Volume ratio (v/v)		PAN–PTh content (%)	Surface resistivity (MΩ/cm ²)
Acetonitrile	Chloroform		
1	0	0.5	1.6×10^4
3	1	2.3	350
1	1	2.5	341
1	3	3.8	3
1	5	4.8	2
0	1	2.0	3×10^5

Total solvent volume: 12 mL, aniline/thiophene mol ratio: 1/3, mol of total aniline/thiophene: 5 mmol, FeCl₃/aniline-thiophene mol ratio: 1/1, polymerization temperature: 20°C, polymerization time: 60 minutes.

slices having 20 micron thicknesses with a Shandon Finesse 325 microtone after embedding the fiber samples in paraffin. The optic microscope images of the cross sections were recorded with a Leica DM LS 2 microscope.

The pH effect study on the PAN–PTh/PET and PAN/PET composites was performed by treating with either HCl or NH₄OH solutions with pH values from 5 to 11 at room temperature for an hour, and then the samples were rinsed with distilled water. After drying at 50°C in a vacuum oven, the surface resistivity of the composites was measured.

In the domestic laundering process, a composite sample was washed with 50 mL of 0.4% (w/v) commercial detergent (the composition was 15–30% carbonate, 5–15% anionic active and less than 5% nonionic active materials) containing solution at room temperature at 300 rpm for 1 h and then rinsed with distilled water. In commercial laundering, C₂Cl₄ (dry cleaning liquid) was used. At the end of both processes, samples were dried in a vacuum oven at 50°C. Domestic and commercial laundering processes were repeated for five cycles and surface resistivity was measured followed each washing cycle.

RESULTS AND DISCUSSION

In the first experiments, PET fiber samples were directly used in the polymerization without any swelling pretreatment. Although the polymerization conditions were changed, the highest PAN–PTh content (%) of composite fibers was 2% and the lowest surface resistivity was measured as 24 MΩ/cm². This resistivity value was higher than that from PAN/PET and PTh/PET conductive composite fibers reported in our previous studies;^{15,21,22} consequently, the PET samples were swollen in dichloromethane which is known as a swelling agent for PET fibers,²³ at boiling temperature for 2 h, and these fibers were used in experiments.

Solvent Effect

It is known that thiophene is unstable and gives a non-conjugated polymer structure in aqueous acidic medium which is favorable for the polymerization of aniline.^{24,25} The yield and conductivity of PTh also change according to the polarity of solvent types and solvent mixtures used as polymerization media.²⁶ Therefore, pure chloroform and acetonitrile and their

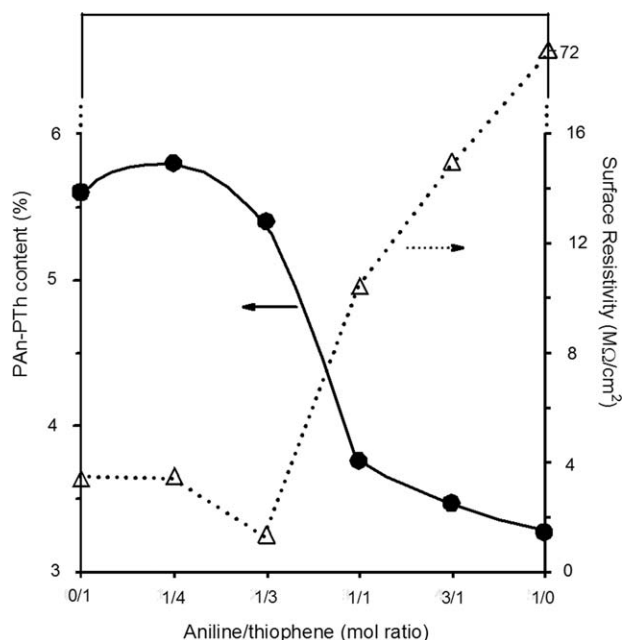


Figure 1. The changes in PAN–PTh content (%) and surface resistivity of PAN–PTh/PET composite fibers with aniline/thiophene mol ratios (mol of total aniline/thiophene: 5 mmol, FeCl_3 /aniline–thiophene mol ratio: 1/1, acetonitrile/chloroform volume ratio: 1/5, total solvent volume: 12 mL, polymerization temperature: 20°C, polymerization time: 60 minutes).

mixtures having different volume ratios were used as the polymerization media in preparation of conductive PAN–PTh/PET composite fibers (Table I).

Although a homogenous green-black colored composite fiber was obtained in the acetonitrile medium, a measurable increase was not observed in fiber weight as shown in Table I. The surface resistivity of the composite fiber was also measured to be $1.6 \times 10^4 \text{ M}\Omega/\text{cm}^2$. With the increment of the chloroform volume ratio in the solvent mixture, the PAN–PTh content of the composite increased and the surface resistivity decreased. The highest PAN–PTh content (4.8%) and the lowest surface resistivity ($2.0 \text{ M}\Omega/\text{cm}^2$) could be obtained at a 1/5 volume ratio of acetonitrile/chloroform mixture. Although a 2% increase in composite fiber weight was observed in the pure chloroform medium, the surface resistivity was a comparatively high value ($3 \times 10^5 \text{ M}\Omega/\text{cm}^2$). Moreover it was observed that the

PAN–PTh/PET composite lost its fiber resilience and had a brittle structure in the pure chloroform medium. This phenomenon could be explained by the possible formation of highly concentrated HCl as a by-product from the reaction between FeCl_3 and CHCl_3 ,²⁷ which could degrade the PET fiber. Moreover, chloroform is much more stable to chemical oxidative polymerization conditions compared to acetonitrile, but since the solubility of FeCl_3 is very limited in chloroform,²⁸ the conductive polymer was more likely to form in the polymerization solution as aggregates, and this may have led to a decrease in the amount of the polymer that coated the composite.

At the solvent volume ratios where the acetonitrile volume was high, the decrease in PAN–PTh contents can also be attributed to the formation of an acetonitrile– FeCl_3 coordination complex, due to the high dipole moment of acetonitrile, and this coordination compound participates various side reactions.^{26,29} Due to these side reactions, the oxidant effectiveness of FeCl_3 decreases and the polymer yield drops.

The Effect of Aniline/thiophene Mol Ratio

When the aniline/thiophene mol ratio was higher than 1/3, the conductive polymer content of the composite fiber decreased and the surface resistivity increased (Figure 1). At this mol ratio, the lowest surface resistivity was measured as $1.3 \text{ M}\Omega/\text{cm}^2$, and the conductive PAN–PTh content of the composite fiber was 5.4%.

In Table II, the results of the elemental analysis of the PAN–PTh/PET composites and PAN–PTh polymers with different aniline/thiophene mol ratios are given. At only a 1/3 aniline/thiophene mol ratio, sulphur (S) could be detected and its value was 0.49%. With the calculation made from this S ratio, 74.6% of PAn and 25.4% of PTh were found in the polymers coated to the composite fiber. Similar to the composite's elemental analysis, the presence of S in the PAN–PTh polymers could only be observed at a 1/3 aniline/thiophene molar ratio as a value of 1.13%. In the calculations made from this S value, the percentages of aniline and thiophene were found to be 90.9% and 9.1%, respectively. Similar results were reported in the electropolymerization of the aniline and thiophene mixtures. Abacı *et al.* could not detect S using elemental analysis in the polymer mixture when the thiophene amount was lower than 5/3 in an aniline/thiophene mol ratio.¹⁷ The conversions (%) of aniline and thiophene monomers were also calculated from the elemental

Table II. Elemental Analysis of PAN–PTh/PET Composite and PAN–PTh Polymers Obtained at Different Mol Ratios of Aniline/Thiophene

Aniline/Thiophene mol ratio	PAN–PTh/PET composite		PAN–PTh polymers		Monomer conversion (%) ^a	
	N (%)	S (%)	N (%)	S (%)	Aniline	Thiophene
1/4	0.74	0.69	6.80	2.07	54.4	2.3
1/3	0.64	0.49	4.95	1.13	68.6	2.9
1/1	0.36	0	6.68	0	70.8	-
3/1	0.43	0	7.89	0	63.0	-

^a Calculated from elemental analysis results of each PAN–PTh/PET composite and PAN–PTh polymers.

Mol of total aniline/thiophene: 5 mmol, FeCl_3 /aniline–thiophene mol ratio: 1/1, acetonitrile/chloroform volume ratio: 1/5, total solvent volume: 12 mL, polymerization temperature: 20°C, polymerization time: 60 minutes.

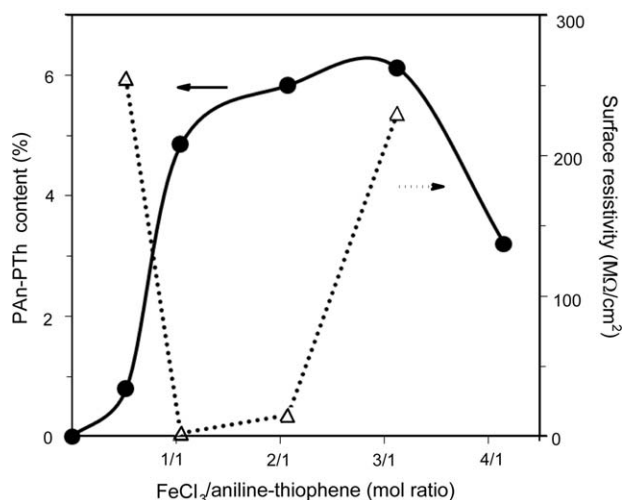


Figure 2. The changes in PAN-PTh content (%) and surface resistivity of PAN-PTh/PET composite fibers with FeCl_3 /aniline-thiophene mol ratio (aniline/thiophene mol ratio: 1/3, mol of total aniline/thiophene: 5 mmol, acetonitrile/chloroform volume ratio: 1/5, total solvent volume: 12 mL, polymerization temperature: 20 °C, polymerization time: 60 minutes).

analysis results of each PAN-PTh/PET composite and PAN-PTh polymers having different aniline/thiophene mol ratios.

The Effect of FeCl_3 /aniline-thiophene Mol Ratio

It can be seen from Figure 2 that the conductive polymer content of the composite fiber increased up to a 3/1 FeCl_3 /aniline-thiophene mol ratio and dramatically decreased at higher ratios. On the other hand, the surface resistivity of composite fibers decreased up to a 1/1 mol ratio and significantly increased at higher ratios.

It was indicated in the literature, in which the separate polymerization of aniline and thiophene with FeCl_3 was conducted to

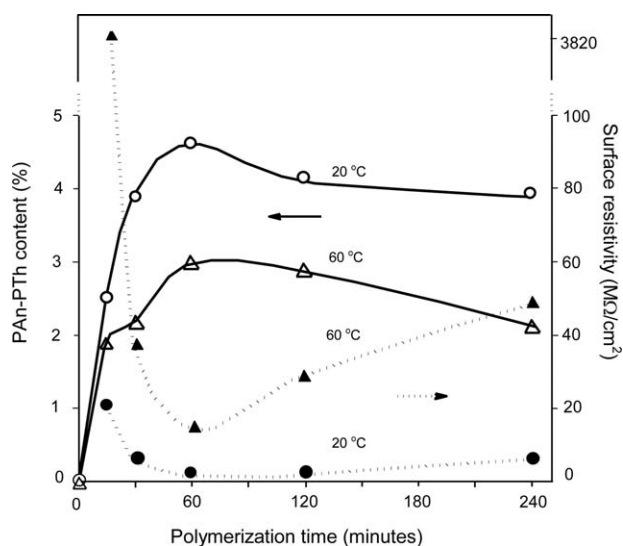


Figure 3. The changes in PAN-PTh content (%) and surface resistivity of PAN-PTh/PET composite fibers with polymerization temperature and time (aniline/thiophene mol ratio: 1/3, mol of total aniline/thiophene: 5 mmol, FeCl_3 /aniline-thiophene mol ratio: 1/1, acetonitrile/chloroform volume ratio: 1/5, total solvent volume: 12 mL).

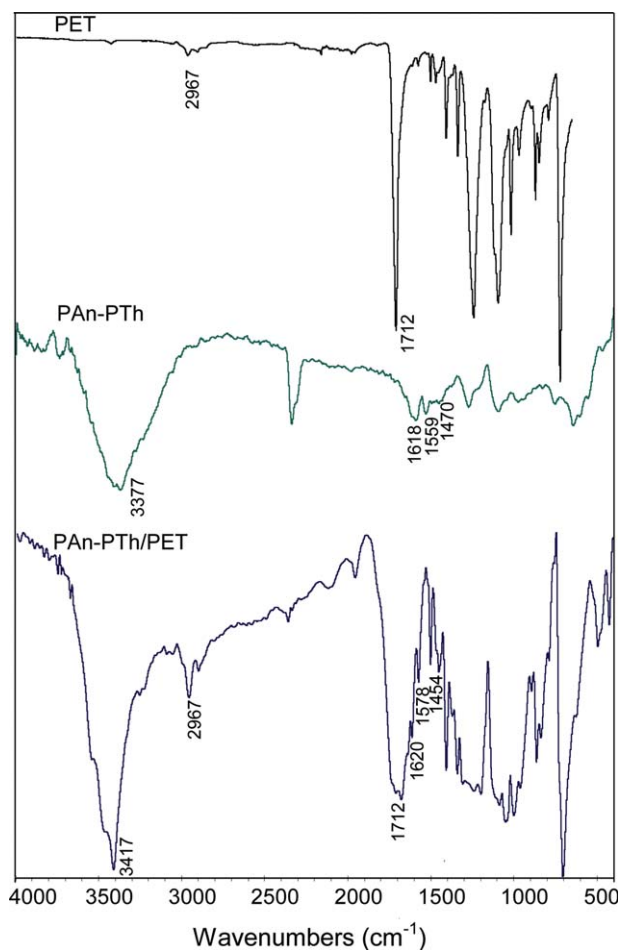


Figure 4. FTIR spectra of PET fiber, PAN-PTh polymers and PAN-PTh/PET composite fiber. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

obtain a polymer with high conductivity, that the optimum oxidant/monomer mol ratios should be 2.5/1³⁰ and between 3/1¹⁵ and 4/1,³¹ respectively.

In our study, at the 1/1 FeCl_3 /aniline-thiophene mol ratio where the lowest surface resistivity was obtained, the

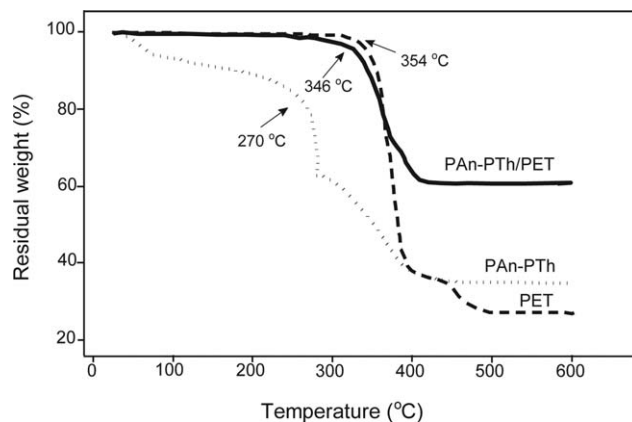


Figure 5. TGA curves of PET, PAN-PTh polymers and PAN-PTh/PET composite fiber.

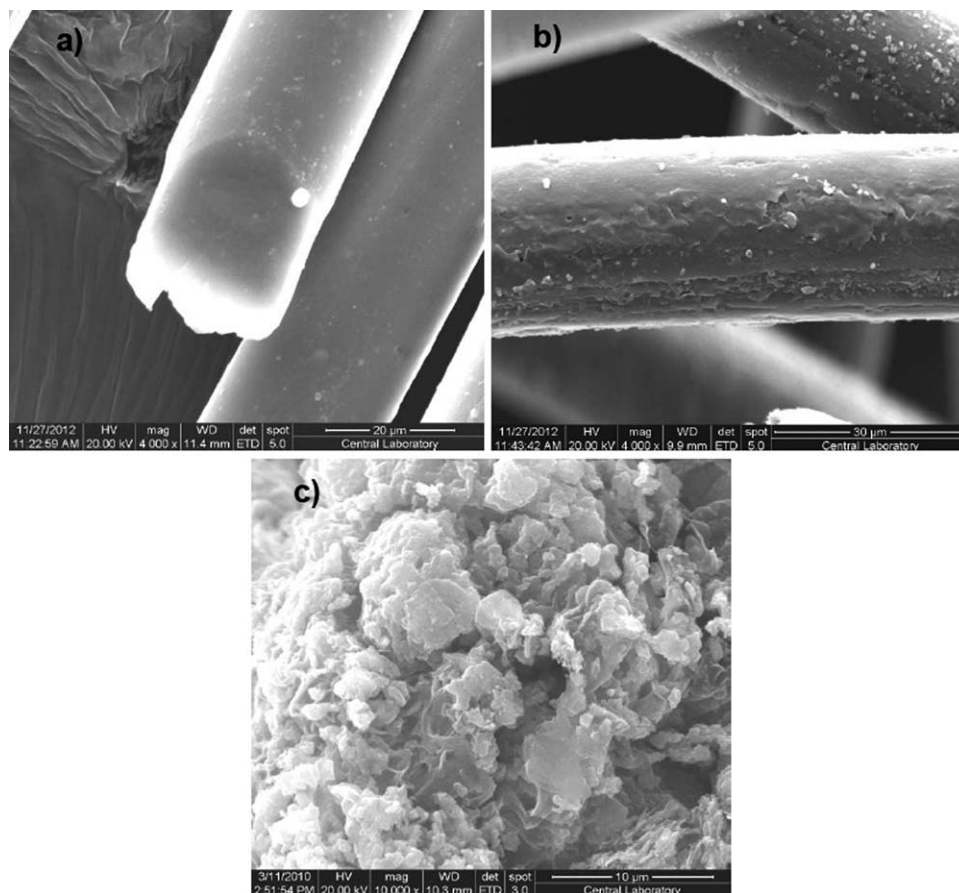


Figure 6. SEM micrographs of (a) PET fiber, (b) PAN-PTh/PET composite fiber and (c) PAN-PTh polymers.

FeCl_3 /aniline and FeCl_3 /thiophene mol ratios were separately calculated as 4/1 and 1.3/1, respectively. Since the FeCl_3 /aniline mol ratio was greater than the value reported in the literature, the excess FeCl_3 may have caused over-oxidation of PAN chains and this could have led to interruption in the π conjugated structure of PAN.

The Effects of Polymerization Temperature and Time

The effects of polymerization temperature and time on PAN-PTh content (%) and surface resistivity of the composite fibers were studied at 20°C and 60°C and the results are given in

Figure 3. As can be seen in the figure, the PAN-PTh content (%) of the composite decreased at 60°C. With increasing temperature and depending on the stronger oxidizing ability of the oxidant as well as the raise in the reaction rate, this favored the formation of excess amounts of monomeric active centers and as a result of spreading monomers to these active centers, soluble oligomeric types in the polymerization media may have occurred. Therefore, the polymer yield decreased, and the polymer chains coated to the fibers would be shorter which was favorable for polymer solubility.²⁹ The increase in the surface resistivity with increasing polymerization time (Figure 4) could

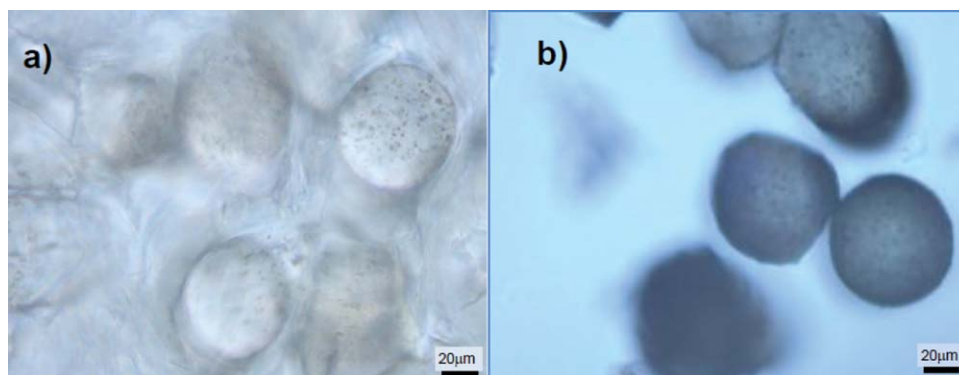


Figure 7. The cross-section images of (a) PET fiber and (b) PAN-PTh/PET composite fiber. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Table III. The Changes in Surface Resistivity of PAn-PTh/PET and PAn/PET Composite Fibers with pH

pH	Surface resistivity ($M\Omega/cm^2$)	
	PAn/PET	PAn-PTh/PET
5	114	36
7	420	52
9	540	60
11	560	270

Initial surface resistivity values of PAn-PTh/PET and PAn/PET are $1.9 M\Omega/cm^2$ and $82 M\Omega/cm^2$, respectively.

also arise from breakages that could be observed in the polymer chain.³²

FTIR

The FTIR spectra of PET fibers, PAn-PTh polymers and PAn-PTh/PET composite fiber are given in Figure 4. As seen in the figure, the band observed in the composite fiber's spectrum around $3400\text{--}3500\text{ cm}^{-1}$ is characteristic NH stretching showing the presence of a secondary amine group of PAn in the PAn-PTh polymers between $3300\text{ and }3400\text{ cm}^{-1}$.^{33,34} The bands observed at 2967 cm^{-1} and 1712 cm^{-1} correspond to the C-H and C=O stretching of PET, respectively. The bands around 1454 cm^{-1} and 1620 cm^{-1} belong to the symmetric C-C stretching of PTh and C-C stretching vibrations in both PTh and PAn aromatic rings, respectively.³⁵ The band at 1578 cm^{-1} could be assigned to C=N and C=C stretching in quinoid-diimine units of PAn.^{36–38}

TGA

The thermal stability behaviors of the PET fiber, PAn-PTh polymers and PAn-PTh/PET composite fiber were examined and are shown in Figure 5. It can be seen from the thermograms that the PAn-PTh polymers had a 32% weight loss in the temperature range $100\text{--}270^\circ\text{C}$, and this weight loss originated from the removal of moisture and dopants present in the polymers. For PET fibers, the decomposition temperature observed at

Table IV. The Changes in Surface Resistivity of PAn-PTh/PET Composite Fiber with Domestic and Commercial Laundering

Process	Washing cycle	Surface resistivity ($M\Omega/cm^2$)
Unwashed	-	1.3
	1	2.3 ^a
Domestic laundering	2	6.2 ^a
	3	12.0 ^a
	4	76.0 ^a
	5	14.8
Commercial laundering	1	7.5
	2	11.0
	3	11.5
	4	11.9
	5	14.8

^a The surface resistivity values of samples washed with domestic laundering were taken after doping with 0.5M HCl.

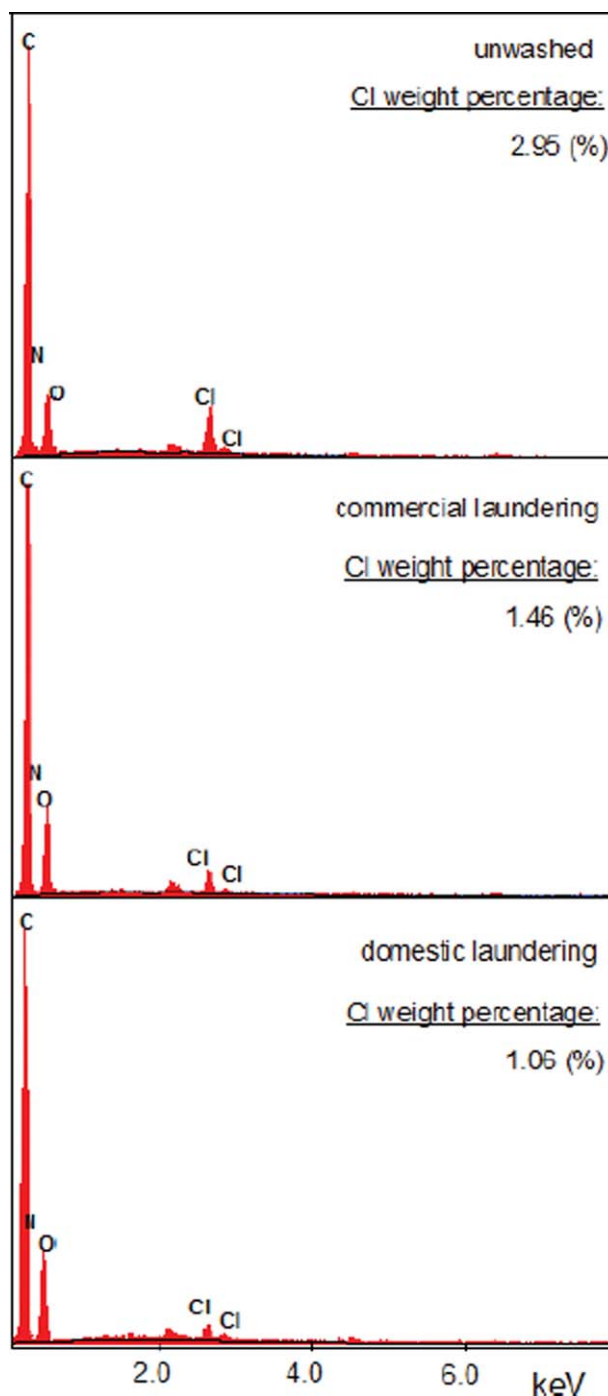


Figure 8. EDX spectra and Cl^- weight percentages (%) of unwashed and washed PAn-PTh/PET composite fibers with domestic and commercial laundering. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

354°C decreased to 346°C with the incorporating of PAn-PTh polymers in the PET structure, which shows that the thermal stability of the composite slightly decreased in terms of decomposition temperature. However, while the composite lost 39% of its total weight up to 600°C , the PET and PAn-PTh polymers lost 73% and 65%, respectively. Therefore, it was determined that the thermal stability of the PET fiber was partially

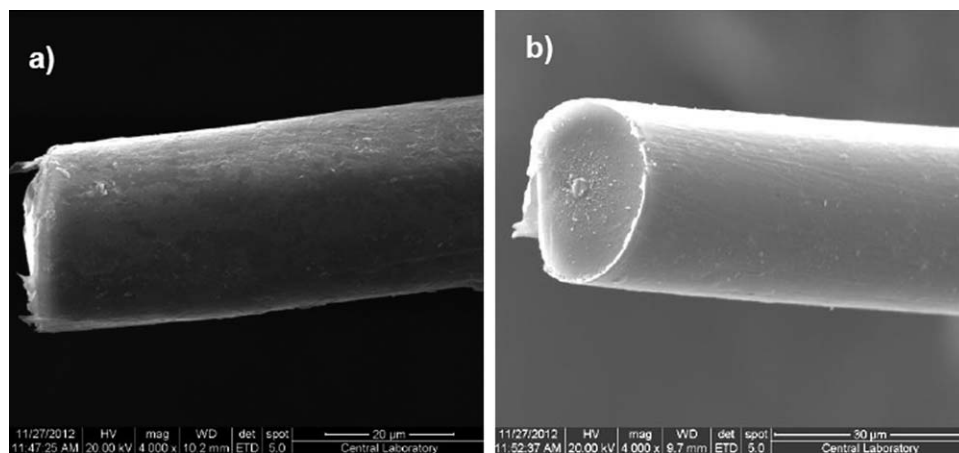


Figure 9. SEM micrographs of PAN–PTh/PET composite fiber washed four cycles with (a) domestic laundering and (b) commercial laundering.

increased in terms of the reduction in weight loss up to 600°C after conductive polymer coating.

SEM and Cross-Section

The micrograph of the composite fiber showed that the PAN–PTh polymers were uniformly coated on the fiber's surface together with some polymer particles on the coating (Figure 6). Moreover, no deformation was observed in the longitudinal image of the fiber. In the studies where PAN and PTh were separately coated on the fiber's surface, it was reported that the coatings of PAN and PTh had a morphology of agglomeration and partially coherent particles.^{7,9} In our study, the homogeneous polymer coating the fiber could be explained by the effect of the swelling of the PET in an organic solvent before polymerization on the incorporation of PAN and PTh on the PET fiber. Huang *et al.* also reported that, to obtain a homogeneous PAN coating on PET surfaces, it was favored to use an alkali pre-treated PET fiber.³⁹

The cross-section images of PET and PAN–PTh/PET composite fibers showed that the conductive polymer coating was limited to the surface of the PET fiber and there was no progress toward the fiber center. In addition, no change in the cross-section appearance of the fiber was observed after coating (Figure 7).

pH Effect

The effect of pH on the surface resistivity of PAN–PTh/PET composite was evaluated after treating with different pH solutions with values between 5 and 11, and compared with a PAN/PET composite prepared under the same polymerization conditions (Table III). As seen from the table, the surface resistivity of both composite fibers increased with alkalinity of the solution. While the surface resistivity of the PAN–PTh/PET composite fiber showed a 1.7 fold increase from pH 5 to 9, the resistivity of the PAN/PET composite increased 4.7 fold. At the highest pH value of 11, the surface resistivity of the PAN–PTh/PET and PAN/PET composite fibers reached 270 MΩ/cm² and 560 MΩ/cm², respectively. The results indicate that the surface resistivity of the PAN–PTh/PET composite was affected less by the pH of the solution compared to the PAN/PET composite due to the presence of PTh in the polymer mixture coated on the PET. The increase in the surface resistivity at high pH values

could be explained with the transition of the PAN structure from protonated emeraldine form to emeraldine base form that has low conductivity.⁴⁰

Washing Durability

The washing durability of the conductive PAN–PTh/PET composite fibers was determined by monitoring the changes in the surface resistivity after two different washing processes: domestic and commercial laundering using a detergent solution and C₂Cl₄, respectively. In the domestic laundering, it was observed that the color of the composite fiber turned from green to blue and the surface resistivity increased 10⁴ fold during the first washing step. We concluded that this observation was as a result of the removal of dopant anions from the composite.⁴¹ After redoping same sample with 0.5M HCl, it was observed that the surface resistivity significantly decreased and returned to the original value. The surface resistivity values measured after five cycles of the washing-redoping process are summarized in Table IV. As can be seen from the table, the surface resistivity increased and reached 76 MΩ/cm² after four washes and did not change remarkably with a further wash. However, at the fifth domestic laundering, the composite fiber was felted.

In commercial laundering, the surface resistivity of the composite fiber also increased and reached 11.9 MΩ/cm² after four washes. Significant changes in surface resistivity were not observed with further washing cycles. Additionally, no felting was observed after the fifth wash compared to domestic laundering.

In the literature, there have been some reports related to increases in the surface resistivity of conductive polymers and fiber composites with detergent washing.^{8,42} For instance, after washing a PAN–HSO₄[−] coated PET fabric with domestic laundering using a reference detergent, the surface resistivity of the sample increased from 49 Ω to 10¹⁰ Ω.⁸ In another study it was also reported that the conductivity of a PAN/Nylon 6 composite fabric decreased after home laundry performed with an alkali detergent and tap water.⁴²

The weight percentage (%) values of dopant Cl[−] anions obtained from the EDX analysis of unwashed and washed composites with domestic and commercial laundering can be seen in Figure 8.

The weight percentage of Cl^- anions in the domestic laundering was lower than in the commercial laundering. This may be explained by the easy removal of Cl^- anions from the PAN–PTh/PET composite after washing with detergent. But the less amount presence of Cl^- anions in the composite after detergent washing may have preserved its conductivity in some degree.

SEM micrographs of washed composites with domestic laundering [Figure 9(a)] and commercial laundering [Figure 9(b)] showed that some polymer particles on the fiber's surfaces disappeared when compared to the unwashed composite (Figure 6). The polymer coating on the PAN–PTh/PET fiber surface was homogeneous and no flaking areas were observed after domestic and commercial laundering.

CONCLUSIONS

Our results showed that the conductive PAN–PTh/PET composite fiber could be prepared by polymerization of aniline and thiophene in the presence of PET fibers. It was found that the change in the volume ratios of the acetonitrile/chloroform as the polymerization medium played a key role in terms of both PAN–PTh content (%) and surface resistivity of the composite fibers. Element analysis showed that the PAN amount was more than the PTh in the PAN–PTh polymers coated with composite or polymer as formed in the polymerization medium. TGA analysis confirmed that the thermal stability of the composite partially increased compared to pure PET in terms of residual weights at 600°C . It was proven from the cross-section images that the conductive polymer coating was limited to the surface and the appearance of the fiber's cross-section was unchanged. One of the significant observations is that the change in surface resistivity of the PAN–PTh/PET composite with pH was less than the PAN/PET composite. The EDX results and SEM micrographs clarified that although the dopant Cl^- anions were partially removed with the domestic and commercial laundering, the homogeneity of the PAN–PTh coat on the fibers was preserved and no flaking was observed.

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