

Electrical Resistivity Studies on Polyaniline Coated Polyester Fabrics

R. Neelakandan and M. Madhusoothanan

Department of Textile Technology, Anna University, Chennai, INDIA

Correspondence To:

M. Madhusoothanan, email: mmadhu@annauniv.edu

ABSTRACT

The effect of fabric parameters such as type of weave and pick density on electrical surface resistivity of polyaniline coated fabric was studied. The fabric structure greatly influences the fabric electrical resistivity. Among the samples tested the twill structure with high picks per inch shows lower surface resistivity. The plain structure which has more interlacement points shows higher resistivity.

Keywords: Electrically conductive fabric, Polyaniline, Fabric structure, Electrical resistivity, Coating

INTRODUCTION

The intrinsic conducting polymer (ICP) has been identified as an important material due to its high conductivity closely reached the level of metals. Its metallic nature has created interest in these polymers in many fields, such as electromagnetic shielding, energy storage and ESD materials [1]. In recent times, among the various conducting polymers, polyaniline has become an important class of ICP because of its ease in synthesis, high conductivity, and excellent stability [2],[3]. However, the infusibility and poor mechanical properties are the major problem that encumbered it from successful commercialization [4]. The shortcomings in polyaniline can be mitigated by blending them with conventional polymers, such as polypropylene, poly (methyl methacrylate), and poly styrene [5]. However, the structural homogeneity will not be maintained in the blend system [6]. Coating of conducting polyaniline on to a flexible substrate such as textile fabrics and sheets can retain the flexibility of

the fabrics and the electrical conductivity of the conducting polymers [7],[8],[9],[10]. The electrical conductivity of polyaniline coated textile structures can be assorted by varying the concentrations of monomer, dopant, oxidizing agent and the polymerization parameters such as time and temperature [11]. However, the amount of polymer deposition i.e. thickness of the coated layer can directly influence the fabric electrical conductivity. It is known that, in any coating process, apart from chemical concentrations, the nature of substrate and the method of coating has a direct influence on polymer deposition. In chemical oxidative coating process, first the prepolymer solution i.e. monomer and dopant diffuses into the yarn structure and covers the fibers. The conducting polyaniline will form on further addition of oxidizing agent. The diffuseability of the prepolymer solution is generally affected by the structural nature of the fabric and the number of threads per unit area. It is an established fact that in woven fabrics a small change in yarns interlacement pattern changes the fabric properties such as tensile strength, bending, permeability and porosity. Many research works have been carried out on studying the electrical characteristics of conducting fabric by varying the concentrations of monomer, dopant and oxidizing agent [12], [13], [14]. But no work has been reported on the effect of fabric parameters on electrical resistivity. In this work, an attempt has been made to study the effect of different basic weaves such as plain, twill and satin with varying picks per inch on fabric electrical conductivity, as this will help in choosing a proper fabric for making conductive fabric for ESD and EMI applications.

MATERIALS AND METHODS

Materials

Polyester yarn of 34D was used in both warp and weft directions to prepare fabric samples of plain, twill (2/1) and satin (5 end satin) structures with varying picks per inch (50, 60, 70 and 80). Aniline was used as a monomer, HCL and ammonium persulfate were used as dopant and oxidizing agent respectively.

Synthesis of Conductive Fabric

0.1 M aniline monomer was combined with 1 M of aqueous HCL in a reaction vessel and then the polyester substrate was placed inside. 0.125 M of oxidizing agent in an aqueous form was prepared separately and then added into the reaction vessel to initiate the polymerization process. The chemical in situ polymerization was carried out at room temperature (30°C) for about 2 hours with occasional stirring.

SEM Observation

The morphology images of uncoated and coated samples were taken by using Scanning Electron Microscope (JEOL, type JSM 820, Japan) operated at 5 KV. All the samples were first coated with a thin layer of gold by sputtering and then exposed in SEM for taking images.

Electrical Resistivity Measurements

Electrical resistance measurements were performed on all samples after conditioning the samples in a standard atmosphere. The resistance was measured ten times on each side of the sample and the average values were taken. The American Association of Textile Chemists and Colourists (AATCC) test method 76-1995 was used to measure the resistance of the samples and the surface resistivity of the fabric was calculated as follows

$$R = R_s (l / w)$$

Where, R is the resistance in ohms, R_s is the sheet resistance or surface resistivity in ohms/square, l is the distance between the electrodes, w the width of each electrode.

RESULTS AND DISCUSSIONS

Effect of Fabric Structure on Electrical Resistivity

Figure 1 elucidates the effect of fabric structure on fabric DC (direct current) surface electrical resistivity in both warp and weft direction. Figure suggests that, the fabric structure i.e. the interlacement pattern between warp and weft yarns plays a crucial role in the electrical resistivity of the fabric. In general, it is expected that, the fabric resistivity between all structures should be more or less same due to the similar polymerization conditions followed for all the fabric samples. But the results show variations between fabrics structures. This suggests that, the flow of charge in the fabric is not only taking place on the fabric surface, it also travels along the yarn cross section.

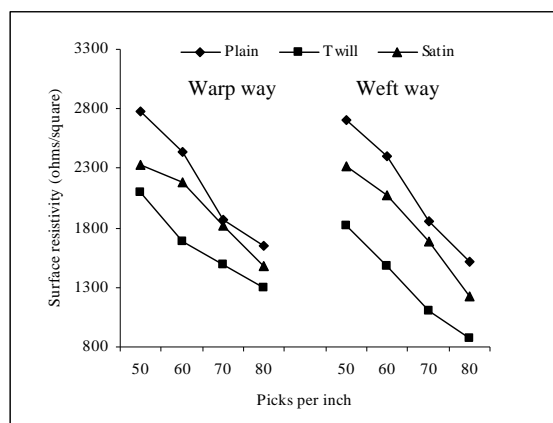
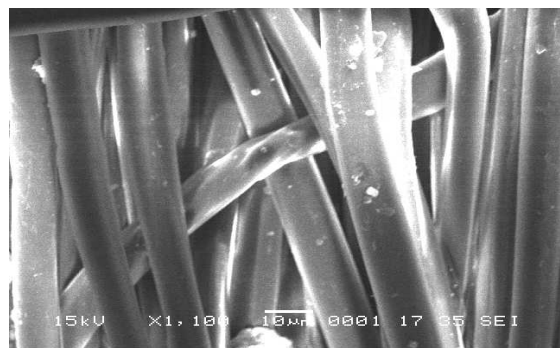
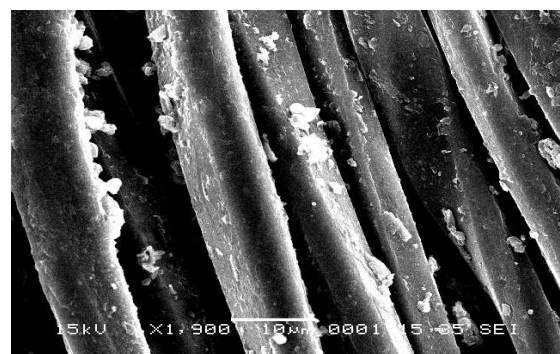


FIGURE 1. Surface resistivity of polyaniline coated fabrics

In the in-situ polymerization process used in this study, the fabric is exposed to monomer, dopant, and oxidizing agent in the solution. The reaction is initiated by the oxidation of monomer which combines to form dimer, trimer leading to full polymerization. During the polymerization process, the yarns in the fabric which are under tension and compressive force are not exposed completely to the prepolymer solution, which might have reduced the polymer deposition inside the yarn. This can be substantiated from the SEM pictures as shown in the Figure 2, in which it can be clearly seen that, the polymer deposition is not continuous in each filament. The amount of polymer formation and their electrical connectivity in the filament yarn structure may influence the electrical resistivity of the fabrics



a, uncoated fabric



b. polyaniline coated fabrics

FIGURE 2. SEM observation of polyaniline coated fabric

Figure 3 a, b, c shows the model of warp yarn removed from the plain, twill, and satin fabric. The dark portions in the Figure indicate the weft interlacement point, where no or less polymer development would have taken place. With long floats in the fabric structure like twill and satin, the yarn will have greater chance of continuous polymer deposition than in the plain structure. This will give better conduction of charge in twill and satin than in plain fabric. The polymer impregnation in the yarn structure may influence the flow of charge by increasing or decreasing conductive cross section area of the yarn. All the dark spots as shown in the Figure 3 can be considered as a resistor and the plain structure will have more surface resistivity due to the more number of interlacement points.

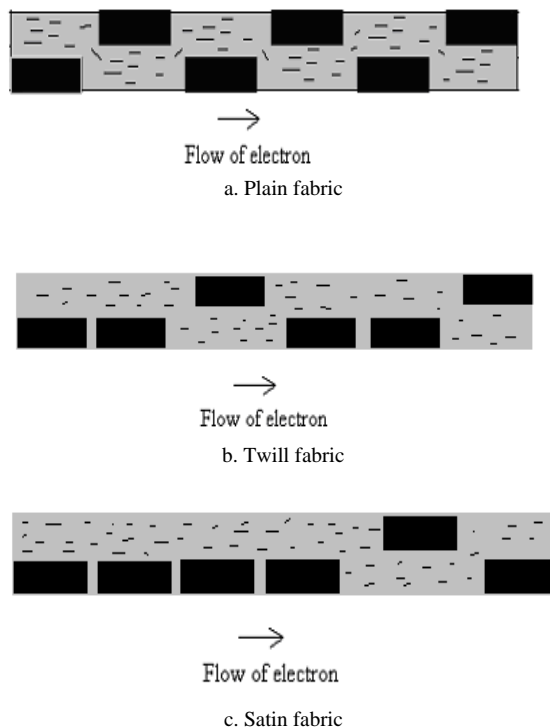
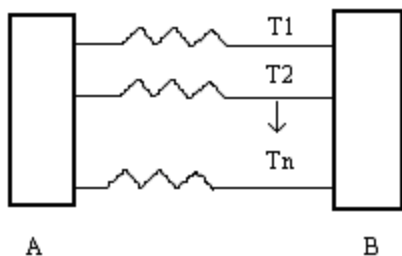


FIGURE 3. Pattern of electron flow in the polyaniline coated yarn removed from the plain, twill, and satin fabric

To substantiate this, the following experiment is carried out. From the fabric samples, all the weft yarns were removed and the electrode was placed on the warp yarns as shown in the Figure 4. All the yarns are connected in parallel between the electrodes. The test was carried out on all samples both in warp and weft directions and the results are given in the Table I&II. It can be clearly seen from Table that, the yarn from the plain fabric has higher resistivity than yarns from twill and satin fabric. This substantiates the fact, that in the interlacement points the polymer deposition is rather poor and the resistances of such yarns are higher.

It can also be observed from Figure 1 that, the resistivity of satin fabric is comparatively higher than twill fabric. This may be due to the fact that, the electric charge flows in the polyaniline coated yarn by two ways, namely along the filament length and across the filaments which is in contact. As the float length increases in the multifilament yarns, the polyaniline coated filaments may lose close contact between the adjacent filaments and the number of electrical conduction path for electrons comes down. So the satin fabric which has longer float length exhibits slightly high surface resistivity than twill fabric.



A, B - Electrodes, T1, T2 ... Tn - Yarns

FIGURE 4. Surface resistivity measurement setup for the yarns in the fabric

Effect of Pick Density

From *Figure 1* it can be seen that, the fabric surface resistivity decreases as the pick density increases. It can be clearly observed in all the fabric structures in both warp and weft directions. This can be attributed to the fact that the increase in pick density makes more conduction path for the flow of electric charge. *Table I & II* shows the surface resistivity of warp and weft yarns of plain, twill and satin fabrics.

TABLE I. Electrical resistivity of fabric and yarns of plain, twill and satin fabric with varying picks per inch in warp direction

		SR _F	SR _{TT}	SR _{ST}
Plain	S1	2781	2558	468114
	S2	2436	2570	470310
	S3	1862	2610	477630
	S4	1644	2690	492270
Twill	S1	2104	2250	411750
	S2	1684	2295	419985
	S3	1492	2310	422730
	S4	1300	2344	428952
Satin	S1	2331	2442	446886
	S2	2179	2451	448533
	S3	1819	2466	451278
	S4	1340	2471	452193

SR_F - Fabric surface resistivity (ohms/Square)

SR_{TT} - Surface resistivity of yarns with out cross yarns (ohms/Square)

SR_{ST} - Surface resistivity of single yarn (Number of yarns x SR_{TT}) (ohms/Square)

S1, S2, S3, S4 -Fabric samples of 50,60,70,80 picks per inch respectively

It is interesting to note from *Table I* that, in all the fabric samples the increase in pick density decreases the fabric surface resistivity in the warp directions but

increases marginally the warp yarn resistivity. This suggests that, the exposure of warp yarns to the polymer solutions is more at low pick density fabric, and this probably increased the polyaniline content on the warp yarns.

TABLE II. Electrical resistivity of fabric and yarns of plain, twill and satin fabric with varying picks per inch in weft direction

		SR _F	SR _{TT}	SR _{ST}
Plain	S1	2704	4680	276120
	S2	2397	3775	268025
	S3	1851	3012	249996
	S4	1515	2512	236128
Twill	S1	1821	3102	183018
	S2	1479	2200	156200
	S3	1099	1812	150396
	S4	876	1454	136676
Satin	S1	2314	4380	258420
	S2	2078	3557	252547
	S3	1683	2854	236882
	S4	1219	2424	227856

It can also be observed in *Table II* that, in the weft direction, the fabric and yarn surface resistivity decreases as the pick density increases. This can be attributed by the fact that, in yarns removed from the fabric with low pick density, one would have thought the polymer development inside the yarn will be better due to this the conductivity will be better or resistivity will be lower compared to yarns removed from fabric with higher pick density. This was expected because the fabric packing will be lower in low pick density fabric which would have helped the chemicals to penetrate in the yarn structure and developed the polymer inside the yarn. But the results give an opposite trend, this is probably due to the fact that, the force exerted on each weft yarn by the warp yarn is higher in low pick density fabric (the number of warp yarn in all the fabric samples are identical) compare to weft yarn removed from high pick density fabric. This would have resulted in weft yarn from lower pick density fabric taking up less polymer resulting in higher resistivity.

CONCLUSION

The electrical resistivity of polyaniline coated fabrics is greatly influenced by the nature of fabric structure and the amount of yarns in the fabric. From this study, it can be concluded that, the structure which has more number of interlacement points can take only fewer amounts of polymers and results poor conductivity. And also the increase in float length reduces the

conduction path in the yarn and fabric. Further, the increase in pick density reduces the surface resistivity by increasing more conduction path for the flow of electric charge. The twill fabric which has moderate interlacement points shows lower electrical resistivity than satin and plain fabric.

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AUTHORS' ADDRESSES

M. Madhusoothanan, Ph.D.

R. Neelakandan

Anna University

Department of Textile Technology

Chennai, 60025

INDIA