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Electrical Surface Resistivity of Polyaniline Coated Woven Fabrics

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Abstract

The process of diffusion polymerization in a mixed bath is used to produce the electrically resistant fabrics such as the polyester, polyester/viscose, viscose, Bamboo, Bamboo/cotton and cotton fabrics and it is done by the in situ chemical oxidative polymerization of conductive polyaniline (PANI) polymer having ammonium persulphate as the oxidant. The electrical resistance of the fabrics have been measured with the help of D.C. regulated variable power supply unit by varying the gauge length from 1", 2" and 3" and input voltage from 20V to 160V. The polyaniline coating evenness was investigated by using Scanning Electron Microscopy (SEM). The test result shows that the electrical resistance decreases with increase in the gauge length and the input voltage and also fabric cover factorshave playing an important role on electrical resistance of the fabrics. The polyaniline coated cotton fabric has less electrical resistance than the polyaniline coated fabrics of the polyester, polyester/viscose, viscose, Bamboo, Bamboo/cotton. The cotton and cotton blend fabrics surface have absorbed more polyaniline particles and hence show more depositions over their surface when compared to that of bamboo, polyester, polyester/viscose and viscose.

Keywords: Polyaniline; Cotton, Polyester; Polyester/Viscose; Gauge length; Surface resistivity

Introduction

In recent years the development of textile based electronics has gained research interest motivated by an increasing demend for multifunctional textiles. Electrical conductive textile fabrics are used to produce various integrated applications like wearable electronics, lighting, rechargeable batteries, electromechanical devices,ammonia sensors, precious metals recovery, electromagnetic shields, static charge dissipation and heating devices etc [1-6]. In recent years polyaniline, polypyrrole and polythiophene are widely used as conducting polymers, but polyaniline has good resistance to environmental, thermal and chemical action, unique electrochemical property, ready availability, low cost of synthesis. It was the first commercially produced polyconjugated polymer. The electrical property of the polyaniline can be modified with protonation/deprotonation and oxidation/reduction process [7,8]. There are different methods used to coat the conductive polymers such as electrochemical polymerization, chemical polymerization, graft polymerization and plasma polymerization. The use of conductive polymers with textile materials has some advantages, such as flexibility with the elimination of the low mechanical properties of the conductive polymers [9]. The factors influencing electrical resistivity of polyaniline coated fabrics are: the amount of the yarns in the fabric, the amount of polymer deposition and the nature of the fabric structure which is evident by the fact that the twill structure with high pick per inch shows lower surface resistivity, the plain fabric has higher resistivity due to more interlacement points [10]. The coating of polyaniline on to a flexible substrate such as textile fabrics and sheet can retain the flexibility of the fabrics and the electrical conductivity of the conducting polymers [11-13]. The fabric has its electrical resistance which is favored by the properties of the conductive fibers, their inter-connection within a fabric and to external circuitry, and the geometry of the fabric [14]. Electrical resistivity of the cotton depends mainly on the layer of wax on its surface which when damaged during the spinning process leads to an increase in its resistivity. The compressional properties of fiber assemblies play a crucial role in the measurement of electrical resistance [15]. The conductivity and colour of the polyaniline depend on the condition of preparation and the form of polyaniline, which is associated with the emeraldine oxidation state [16]. The polymer can be easily prepared by oxidative polymerization with high yield, and it is stable under ambient conditions, PANI impregnated fabrics have better thermal stability [17-20]. When compared with conventional textile fabrics and metal coated fabrics, the polyaniline coated fabric has higher and lower electrical conductivity respectively [19,21,22]. PANI synthesis on textile substrate are influenced by chemical constituents, the reaction parameters, interaction between the deposited polymer and textile substrates [23-25]. The application of textile technology to the production conducting materials is expected to reduce the processing draw backs and new functionality [26]. The literature review shows that there is no relevant publication on electrical surface resistivity of polyaniline coated polyester, polyester/viscose , viscose, Bamboo, Bamboo/cotton and cotton of conductive woven fabrics. Hence this is an attempt has been made to study and analyse the effect of various parameters like gauge length, sample specimen size, effect of types of materials, cover factor, materials blends on electrical surface resistivity of the various fabrics.

Materials and Methods

In this research work, polyester, polyester/viscose, viscose, Bamboo, Bamboo/cotton and cotton materials were selected for the deposition of polyaniline on the surface of the fabrics as shown in the Table 1, in order to analyze the surface resistivity of the materials. In this process, 0.5 M aniline was dissolved in the solution of 0.35 N HCl for diffusion and the mixture was stirred continuously in the bath by magnetic stirrer in order to obtain a homogeneous mixing. All the samples were treated with above solution by padding method at 40°C for 2 hours. 0.25 M ammonium persulphate was dissolved in 0.35N HCl Solution for polymerization. The aqueous oxidizing agent in the

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Sample No.	Yarn Count (Tex)	Material	Blend ratio	EPI ×PPI	Cover factor	Weave
1	20	Polyester	100	46×44	14	Plain
2	20	Polyester	100	55×51	16	Plain
3	20	Polyester	100	68×56	18	Plain
4	20	Poly/Viscose	70/30	46×44	14	Plain
5	20	Poly/Viscose	70/30	55×51	16	Plain
6	20	Poly/Viscose	70/30	68×56	18	Plain
7	20	Viscose	100	46×44	14	Plain
8	20	Viscose	100	55×51	16	Plain
9	20	Viscose	100	68×56	18	Plain
10	15	Bamboo	100	54×50	14	Plain
11	15	Bamboo	100	68×54	16	Plain
12	15	Bamboo	100	76×69	18	Plain
13	15	Bamboo/Cotton	70/30	54×50	14	Plain
14	15	Bamboo/Cotton	70/30	68×54	16	Plain
15	15	Bamboo/Cotton	70/30	76×69	18	Plain
16	15	Cotton	100	54×50	14	Plain
17	15	Cotton	100	68×54	16	Plain
18	15	Cotton	100	76×69	18	Plain

Table 1: Woven fabric technical construction details.

separate bath was slowly added in to the diffusion bath in order to initiate the polymerization reaction. The reaction of polymerization was carried out for one hour at 5°C. After completing the process, the polyaniline coated fabrics were taken out from the bath and rinsed with distilled water containing 0.35N HCL and dried at 60°C. After the polyaniline coating, the fabrics were conditioned at 65% RH and 20°C. The surface resistivity of the conditioned fabrics were tested with the D.C. regulated variable power supply unit, the fabrics were weighed by using Shimadzu single pan balance AY220, Japan (Kyoto).

Scanning electron microscope (SEM)

Surface morphology of the polyaniline treated fabrics were examined by SEM (scanning electron microscope) model JSM 5200(JEOL, Tokyo, Japan) operated at 5KV. All the samples were coated with a thin layer of gold by sputtering and the exposed in SEM for taking images.

Measurement of electrical resistance

The electrical resistivity of a fabric can be measured in the most basic scheme by means of simple resistance probe. To test a fabric samples a small measuring device has been developed. It consists of sample holder, rectifier unit, ammeter and voltmeter and 10 mega ohm discrete resistance. Two bulldog clips are used to hold the sample in the measuring unit gauge length of 1", 2" and 3". The sample is in series with a known resistance 10 mega ohm and is connected with a D.C power supply unit. The input voltage is varying from 20V to 160V in eight steps and the corresponding current through the samples was measured after 10 seconds with the help of multi meter to calculate the resistance of the fabric. The resistance of the fabric can be calculated by using the ohm's law, V=IR, where V=Input voltage and I=current, R is the electrical resistance of the fabric in Ω. The specific resistance of the fabric was calculated using this formula $\rho=RA/L$. Where ρ is the specific resistance of the fabric (unit: Ωm), R is the electrical resistance of the fabric (Ω), L is the length of the sample (unit:m), A is the cross sectional area of the fabric. In this study width of the fabric sample and thickness of the fabric were used to calculate the cross sectional of the fabric.

Results and Discussion

In general the fabric surface resistivity is mainly depends upon the type of materials, blend ratio, cover factor and surface coating materials. The flow of charge in the fabrics not only transfer on the surface of the polyaniline coated fabrics but it also travel along the yarn structure and fabric structure and also the types of fabrics are playing the major important role on electrical surface resistivity. Since the absorption properties of the fabrics are vary from one fabric to other fabrics. So that the electrical surface resistivity and conductivity may be vary from one fabric from another fabric.

SEM analysis

The polyaniline coated cotton, polyester, polyester/viscose, bamboo, bamboo/cotton and viscose fabrics surface views of SEM –Scanning Electron Microscopy at X5000 and 5 μm are shown in Figure 1. From these SEM studies, it clearly understands the polyaniline particles are very evenly deposited over the surface of the cotton, polyester, polyester/viscose, bamboo, bamboo/cotton and viscose fabrics. The polyaniline particles are smoothly distributed over the surface of fabrics structures. The significant amount of polyaniline particles that appeared to be present throughout the fabrics surface, are expected to have considerable influence on the surface resistivity and conductivity of the fabrics. When such depositions are present in the fabrics samples more conductivity can be expected from those fabrics samples. It can be clearly absorbed from the SEM Figure 1 that the cotton and

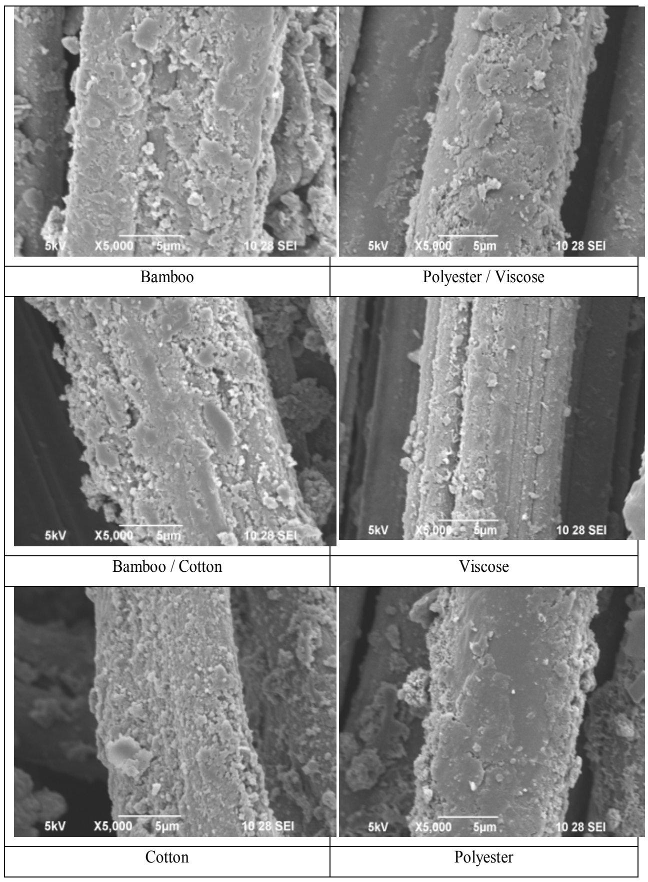

Figure 1: Scanning Electron Microscope (SEM) image of various polyaniline coated woven fabrics.

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cotton blend fabrics surface have observed more polyanilione particles and more depositions over the surface of the fabrics than bamboo, polyester, polyester/viscose and viscose. But in case of viscose fabrics surface have less amount of deposition of polyaniline particles when compare to the other fabrics.

Measurement of electrical resistance

Effect of gauge length on surface resistivity of the fabric: The specific surface resistivity is the measure of capability to with stand surface current flowing along the surface of a material. This characteristic is largely depended upon the ambient conditions and the test specimen. In which the specimen size is one of the important factor to influence the specific surface resistivity of fabrics. From Figures 2-6 shows that the specific surface resistivity of 100% polyester, polyester/viscose (70/30), 100% bamboo, bamboo/cotton (70/30) and 100% cotton respectively under various gauge length like 1” gauge length, 2” gauge length and 3” gauge length and various input voltage of 20V, 40V, 60V, 80V, 100V, 120V, 140V and 160V.

It was observed from Figures 2-6 the specific resistance of fabrics increases with the decreases in gauge length of specimen of polyester, polyester/viscose (70/30), 100% bamboo, bamboo/cotton (70/30) and 100% cotton at input voltage from 20V to 160V. Since surface resistivity is the ratio of D.C voltage per unit length to the surface current per unit width and the surface resistance of polyaniline coated fabrics have directly proportional to the size of the specimen. This trend is true for all types of polyaline coated fabrics (polyester, polyester/viscose (70/30), 100% bamboo, bamboo/cotton (70/30) and 100% cotton). From this we can understand that the insulating property of fabrics increases with the decreases in gauge length. Hence the surface resistivity of the textile materials is also depends upon the gauge length. The gauge length is important factor for analyzing the conductivity and insulating property of textile materials.

Effect of polyanilineon surface resistivity of the various fabrics: The surface resistivity of cotton, bamboo, bamboo/cotton, polyester and polyester/viscose fabrics have greatly influenced by polyaniline coating particles over the surface of the woven fabrics. It was observed from the Table 2 that the polyaniiline coated cotton fabric have low specific resistance than bamboo/cotton, bamboo, polyester and

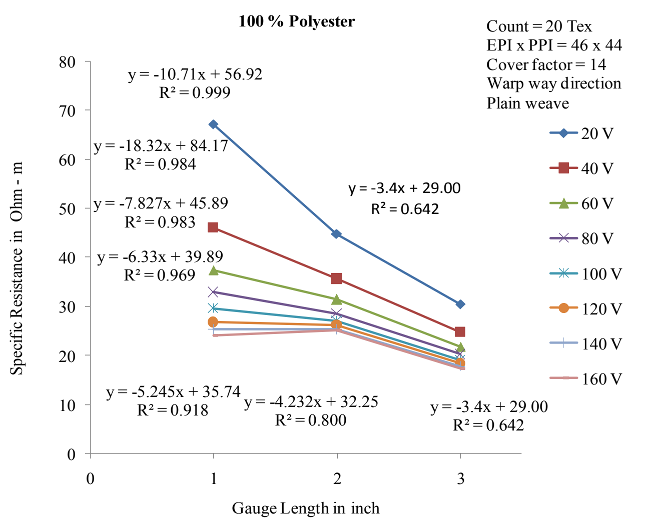

Figure 2: Specific resistance of 100% polyester.

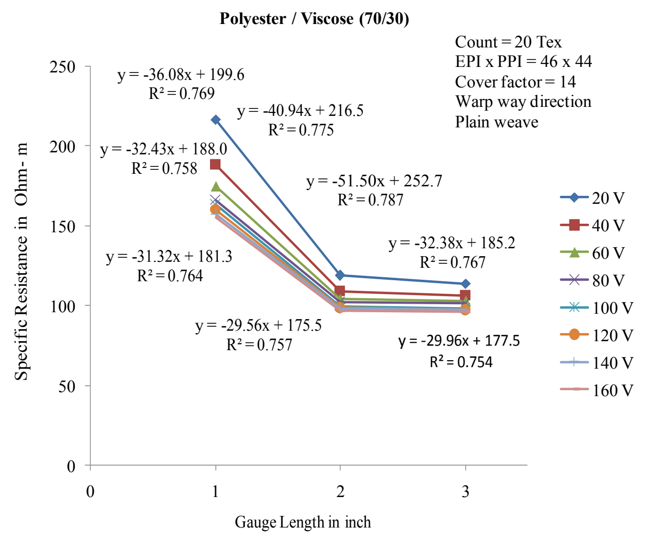

Figure 3: Specific resistance of polyester/viscose (70/30).

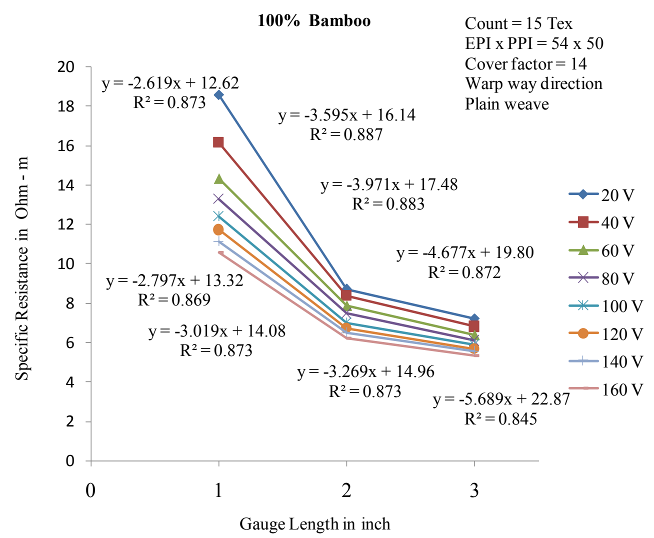

Figure 4: Specific resistance of 100% bamboo.

polyester/viscose at gauge length 1”, 100V, cover factor-14, plain weave. It is mainly due to the absorption properties of cotton materials. The cotton fabrics absorbent properties occur due to a number of reasons, including its specific molecular structure and structure of polyaniline. The cotton materials contain a negative charge which attract the molecules easily and absorbed them quickly. The cellulose in cotton has hydrophilic properties, this makes them to absorb the polyaniline particles uniformly and deposited over the surface of cotton fabrics. Hence polyaniline coated cotton fabrics have low specific surface resistance and good conductivity than the bamboo and polyester and blends woven fabrics. There is significant improvement in surface resistivity and conductivity of the polyaniline coated cotton, bamboo/cotton, bamboo, polyester and polyester/viscose fabrics. It was also observed that the bamboo/cotton and polyester/viscose blends have higher surface resistance than cotton and polyester fabric respectively. There is a significant difference between cotton and polyester fabrics

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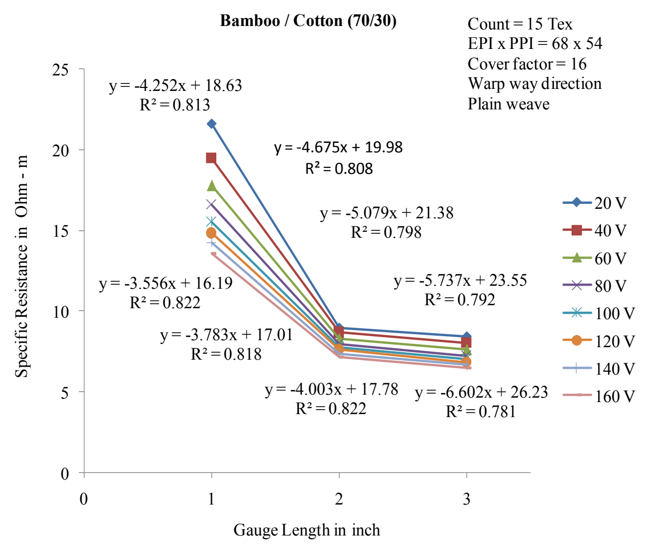

Figure 5: Specific resistance of bamboo/cotton (70/30).

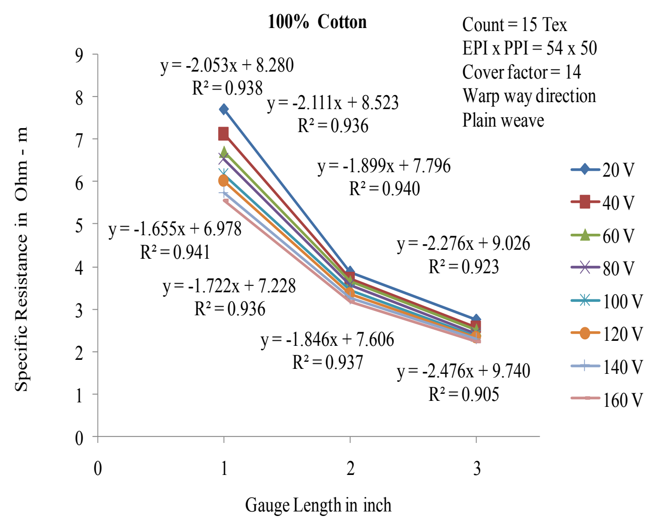

Figure 6: Specific resistance of 100% cotton.

with their blends of bamboo and viscose woven fabrics. The surface resistivity of fabrics is mainly depends upon the resistance to flow of electrical current across its polyaniline coated surface of the fabrics. Hence the amount of deposition of polyaniline materials over the surface of the fabrics is very important for good conductivity and surface resistance of woven fabrics. The amount of polyaniline deposition over the surface of fabrics is mainly depends upon chemical concentration. Hence the surface resistivity and conductivity of fabrics can be varied by changing the concentration of polyaniline chemicals and its composition. The Table 2 shows the amount of polyaniline add on percentage on the surface of the various fabrics. It is also absorbed from Table 2 that polyaniline coated bamboo/cotton fabric have lower surface resistivity than polyaniline coated bamboo fabrics.

Effect of cover factor on surface resistivity of the fabrics: The fabrics cover factors are playing a major role on surface resistivity of the fabrics. It was observed from Figure 7 that when the cover factor

S. No.	Fabric	Specific resistance in Ohm.m	Polyaniline add on %
1	Cotton	6.174	40.35
2	Bamboo/Cotton	8.925	35.22
3	Bamboo	12.413	27.89
4	Polyester	29.597	19.85
5	Polyester/Viscose	163.198	17.74

Table 2: Specific resistance and Polyaniline add on % of polyaniline coated fabrics.

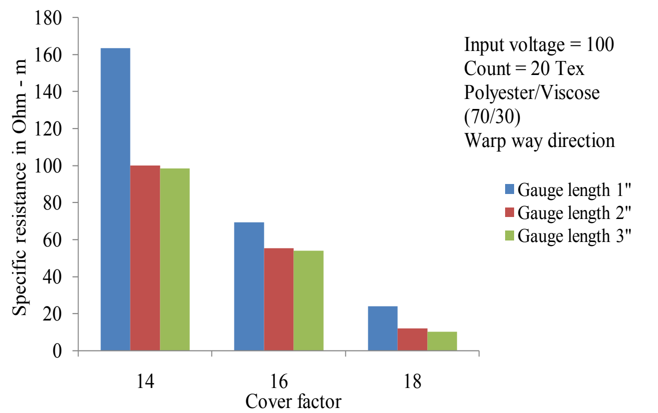

Figure 7: Effect of cover factor of polyester/viscose (70/30).

of fabrics increases, the surface resistivity of the polyaniline coated polyester/viscose and bamboo fabrics decreases. It is mainly due to more number of warp and weft yarn interlacement in the cross sectional area of the fabrics and warp and weft yarns have absorbed more polyaniline molecule in their fiber structures and also polyaniline deposited more in cross sectional area of the surface of the fabrics. So that the surface resistivity of fabrics have been decreased and as well as the conductivity of the fabrics have been increased.

The amount of polyaniline deposition is mainly depends upon the warp and weft yarn interlacement of woven fabrics. Hence the pick density is very important for surface resistivity of woven fabrics. It can be understand that the surface resistivity decreases as the pick density increases in all the fabrics structures. It is mainly due to the increases in pick density makes more conduction path for the flow of electric charges. It also observed that in all the polyaniline coated samples the increases in pick density decreases the fabric surface resistivity in the warp direction and weft direction. There is a significant difference between warp direction surface resistivity and weft way surface resistivity of polyaniline coated cotton, polyester, polyester/viscose, bamboo, bamboo/cotton and viscose. In the entire fabrics sample the fabric surface resistivity decreases in the warp direction as well as increases the conductivity, which is mainly due to more polyaniline content deposition over the warp yarn surface and fiber molecular arrangement in yarn structure.

Conclusion

The electrical specific resistivity of the cotton, bamboo, bamboo/cotton, polyester and polyester/viscose fabrics have greatly influenced by polyaniline conductive coating particles over the surface of the woven fabrics.

- The polyaniline coated cotton fabrics have low specific surface resistance and good conductivity than the other fabrics.

- There is a significant difference between polyaniline coated cotton and polyester woven fabrics with their blends and the blends of bamboo and viscose woven fabrics
- There is a significant difference between warp direction and weft direction specific surface resistivity of polyaniline coated woven fabric
- The cover factors of fabric increases, decreases the surface resistivity of the woven fabrics

The specific resistance of the woven fabrics increases with the decreases in the gauge length.

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