PREPARATION AND CHARACTERIZATION OF ELECTRO-CONDUCTIVE TEXTILES FOR APPLICATION IN HEATING PAD

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Abstract: *A heating pad is very useful for managing the pain by keeping the effected body part warm. It is reusable and can not get contaminated easily.Electrically conductive needle-punched nonwoven polyester fabrics were prepared by in-situ chemical polymerization of pyrrole using suitable oxidant and dopant. Raw polyester needlepunch fabrics were scoured with non-ionic surfactant before the treatment and then they were partially hydrolyzed by caustic soda which would produce active –COOH groups which helped for better fixing of pyrrole monomer on polyester surface. After polymerization fabric samples were dried and surface resistivity measured by electrode probe. Surface Resistivity was obtained. Electrical properties such as voltage-current behavior, voltage-temperature behavior and effect of time on voltage temperature behavior were studied. This fabric was found suitable for heat generation. A heating pad had been fabricated for medical and therapeutic use.*

Keywords: *Heating Pad, Therapeutic, Polypyrrole, Electro-Conductive*

1. Introduction

1.1 General Overview

In the late 1970s discovered conductive polymers. The first material becoming an intrinsically conducting polymer (ICP) was polyacetylene [1], after a doping with iodine. The announcement of this discovery quickly reverberated around scientific community, and intensity of the research for other conducing polymers magnified dramatically. A new generation of polymers was then developed, exhibiting the electrical and optical properties of metals or semiconductors, at the same time retaining the attractive mechanical properties and processing advantages of polymers. Intrinsically conducting polymers were immediately seen as a new route to mimic metallic conductivity, besides the well-know approach to insert conductive fillers into an inherently insulating resin, or to coat a plastic substrate with a conductive metal solution. In this manner, conductive fibers can be prepared to obtain conductive fabrics, or, fabrics already produced can be metalized with a conductive coating. By the way, let us note that metal coated textiles remain fundamental materials, because they generally show a high electromagnetic interference shielding effectiveness (EMI-SE). In fact, intrinsically conducting polymeric materials can be used to obtain rather innovative textiles. These textiles are able to absorb as well as reflect electromagnetic waves, and then can exhibit certain advantages over metallic materials. Actually, the most prominent ICPs in EMI-SE are polypyrrole and polyaniline, where electrical conductivity can have values comparable to those observed for poorly conducting metals and alloy. Among the first commercial products incorporating polypyrrole there was Contex®, a conductive textile product originally manufactured by Milliken, starting around 1990, and now produced by Eeonyx Corp., as EeonTex™. An early application, involving the coating of polyester fibers with polypyrrole (PPy) was the creation of an antistatic fabric. We will also discuss the heat generation obtained from PPy coated fabrics, for suitable applications in textile heating systems. Polypyrrole is in fact one of ICPs very promising for wide thermal electric applications because of its easy preparation with a low cost processing [2].

1.2 Objectives

1) Preparation of an electrically conductive Non-woven fabric by in-situ polymerization of pyrrole.

2) Study of electrical properties of polypyrrole coated non-woven fabric.

3) Fabrication of heating pad for therapeutic use.

2. Materials & Methods

2.1 Materials

1. Polyester Needle punched non-woven fabric (150 GSM)
2. Pyrrole (Leonid Chemicals, India).
3. $FeCl_3$ (Qualigens Fine Chemicals, India)
4. Sodium Hydroxide
5. PTSA [P- Toluene Sulphonic acid Monohydrate LR] (s d fine-chem Ltd., India)
6. Non-ionic Surfactant
7. Sodium Carbonate

2.2 Methods

2.2.1 Scouring

In order to remove any extraneous impurities acquired during manufacturing, the fabric was treated with solution of Sodium Carbonate (1%) solution at 80ºC for 20 minutes, washed further in hot water and then in cold water thoroughly. Treated fabric was then dried in ambient atmosphere and conditioned at standard atmospheric conditions (27ºC and 65% R.H.).

2.2.2 Treatment with NaOH

After washing, the non woven fabric is treated with 5% NaOH solution for 20 minutes. This treatment will help in increasing the add-on percentage of polypyrrole on the fabric.

2.2.3 Polymerization

For in situ polymerization, control polyester sample (25cm×12.5cm) was allowed to soak in 0.5M solution of pyrrole in water for 1 hour at room temperature. The bath containing the fabric was then cooled to ~5ºC and 0.25 M $FeCl_3$ along with 0.05M PTSA (doping agent) solution was added to the bath slowly over a period of 1 hour so as to polymerize the monomer. The M:L ratio was 1:100. This fabric was then thoroughly washed with sufficient amount of water and allowed to dry at 27ºC and RH of 65%. This fabric was black in color resembling polypyrrole.

2.2.4 Measurement of Weight add-on

Weight gain was measured by drying fabric samples in ambient conditions and then conditioning in standard atmospheric conditions (27^0C and 65% R.H.). Weight add-on was calculated on the basis of the difference between the initial and final weights expressed over the initial weight.

2.2.5 Measurement of Surface Resistivity

The relationship between surface resistivity and the surface resistance for concentric ring probe geometry can be found by defining a surface current density in the area between rings. Knowing the surface current density, it is possible to find electric field intensity between the electrode rings. The surface resistivity was measured as per AATCC 76-2005 standard.

2.2.6 Ageing Studies

Ageing studies were conducted by preserving the samples in ambient conditions. The idea is to simulate the degradation behavior of polypyrrole coated fabrics in prevailing atmospheric conditions. Polypyrrole undergoes irreversible loss of conductivity as a result of degradation backbone by the attack of atmospheric oxygen and moisture. For this study samples were protected from direct exposure to sunlight and water.

3. Results & Discussions

3.1 Weight add-on %

Add on percentage of the sample is given by ratio of difference of final weight and initial weight of sample to the initial weight of the sample.

$$= \frac{\text{final weight of sample} - \text{initial weight of sample}}{\text{initial weight of sample}} \times 100$$

$$= \frac{6.61\text{g} - 5.11\text{g}}{5.11\text{g}} \times 100 = 29.35\%$$

3.2 Surface Resistivity

Surface resistivity can be measured using equation:

$$\rho_s = R_s \frac{2\pi}{\ln\left(\frac{R_2}{R_1}\right)} = R_s.K$$

R1 outer radius of the center electrode

R2 inner radius of the outer ring electrode

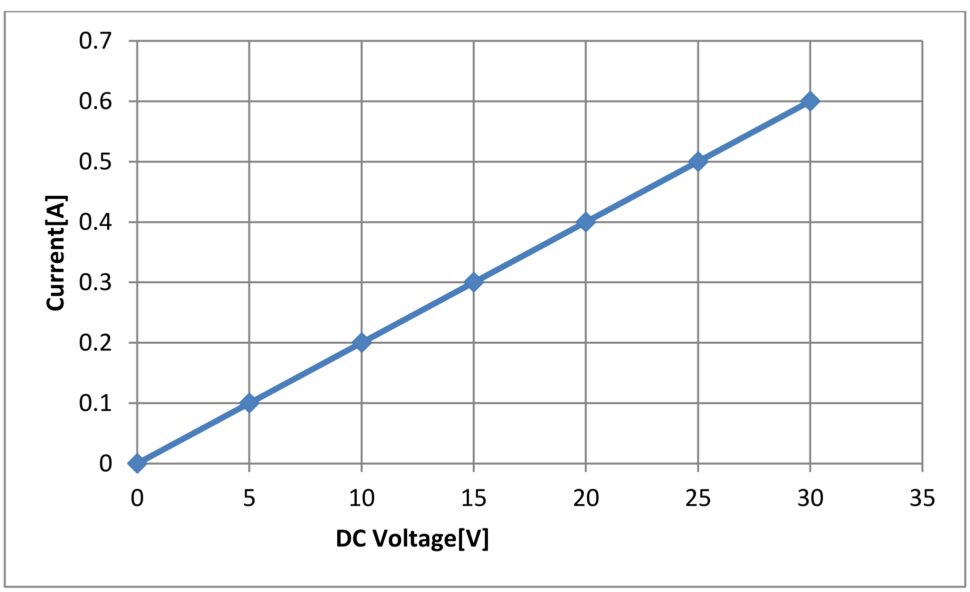
Calculated average value for resistance of PET non woven coated by PPy is R_S= 0.1333 kΩ

Value of constant k = 7.6

Therefore $\rho_S = 1.013\ \mathrm{k\Omega/square}$

3.3 Voltage-Current characteristics of Electro-Conductive Nonwoven fabric

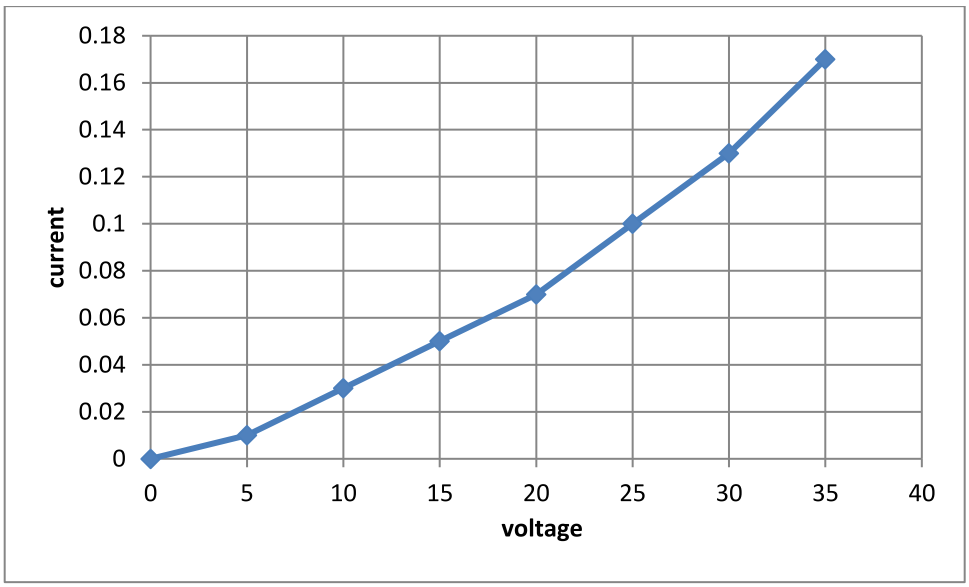
The electrical properties of electro-conductive nonwoven fabric were measured at 27℃ and 65% relative humidity. The fabric sample (25 cm ×12.5 cm) was connected with power supply with help of two steel electrodes. The distance between two electrodes was 10 cm and a voltage of 0 to 30 V was applied. The applied voltage was progressively increased by 2 V and the values of current across the fabric was noted. Subsequently the current versus voltage curve of electro-conductive nonwoven was plotted. It can be seen that as applied DC voltage increases current rises showing a linear behavior. So, it can be interpreted that an electro-conductive nonwoven fabric behaves like a electric conductor.



3.3.1 Voltage-Current Behavior for Repetitive cycle

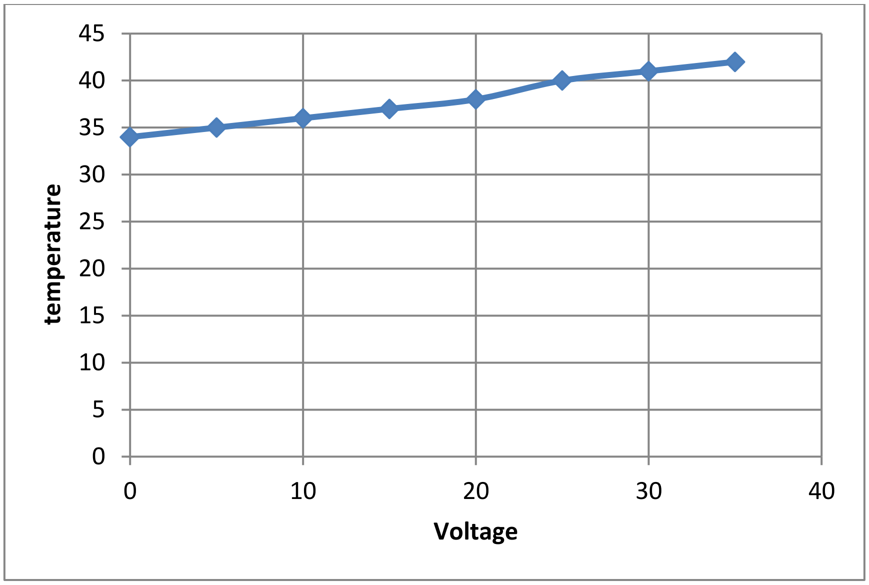
The electrical properties of electro-conductive nonwoven fabric were measured at 27ºC and 65% relative humidity. The fabric sample (25 cm ×12.5 cm) was connected with power supply with help of two steel electrodes. The distance between two electrodes was 10 cm and 0 to 30 V voltage was applied. The voltage was progressively increased by 2 V starting from 0 V increasing upto 35V, then declining in same manner to 0 V completing a cycle and observed the values of current across the fabric. Same cycle was performed repeatedly five times without any time lag.

Five repetitive measurements of V-I characteristics of electro-conductive nonwoven fabric were taken and data was plotted. It can be seen that the performance of the fabric in terms of electrical property did not detoriorate much after consecutive five cycles of measurements.



3.4 Voltage-Temperature characteristics of Electro-Conductive Nonwoven fabric

The voltage temperature characteristics of electro-conductive nonwoven fabric were measured at 27ºC and 65% relative humidity The fabric sample (25 cm ×12.5 cm) was connected with power supply with help of two steel electrodes. The distance between two electrodes was 10 cm and 0 to 30 V voltage was applied. The applied voltage was progressively increased by 5 V and observed the values of surface temperature of the fabric with the help of Infra red thermometer (Signal Hawk Kusam-Meco IRL-300). The voltage versus temperature curve of electro-conductive nonwoven was obtained. It can be seen that with the increase of applied DC voltage, the temperature also rises. So, the fabrics may be used as heating garment or a heating pad for therapeutic use.



3.5 Fabrication of Heating Pad

A PPy coated Polyester needle-punched non-woven fabric 25 cm × 12.5 cm is used as heating element. This textile heating element is connected with the negative and positive terminals of a voltage supplier or battery by the following methods as described below.

3.5.1 Connection with Wires

When the objective is to use the heated fabrics in clothing it is preferred to have connections that are flexible and have low contact resistance. For this purpose fine copper strands were used. The strands were separated and spread out on both sides of fabric. A polyester thread was used to stitch the strands onto the fabric and contact was achieved when the metallic cables were pressed onto the conducting fabric by the thread (figure). The primary advantages of this technique are that the contact achieved is good and the connection is flexible. Now two terminals of this textile heating element have been made for connecting with power supply or battery.

3.5.2 Construction of Pad

Materials used

Outer layer – Nylon Fabric

Inner lining – fine Silk fabric.

Intermadiate material- PPy coated PET needle-punched non-woven fabric

Method

The whole structure was stitched together with outer shell of tarpaulin fabric, innermost fine polyester lining and the PPy coated PET non-woven fabric was inserted between them leaving connections outside. Nylon tape was stitched around the edges locking the whole structure and Velcro was attached.

Characteristics

Dimension 38cm×18cm

4. Conclusions

Conductive needle punched nonwoven polyester fabric was synthesised by in situ polymerisation using pyrrole as monomer in presence of dopant. The surface resistivity, voltage-current behavior, voltage-temperature behavior and effect of time on voltage temperature behavior were studied of the electro-conductive nonwoven fabric and it was found that

1. Developed electro-conductive nonwoven fabric shows good electrical conductivity.
2. The voltage-temperature behavior of the fabric was found suitable for application of heat generation.
3. Time has significant influence in heat generation phenomena.
4. The fabric loses its conductivity with time due to atmospheric aging.
5. As applied DC voltage increases temperature rises so, the fabrics may be used as heating garment or a heating pad for therapeutic use.

5. References

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