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Polypyrrole Based Electro-Conductive Cotton Yarn

Subhankar Maity* and Arobindo Chatterjee

Department of Textile Technology, Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, Punjab-144011, India

Abstract

This work describes a novel method for preparing electro-conductive cotton yarn by *in situ* chemical polymerization of pyrrole with FeCl₃ oxidant and *p*TSA dopant. The mean resistivity 16 Ne yarn is obtained about 182.63 K Ω /m⁻¹ with 11.6% polypyrrole add-on. It is observed that electrical resistivity of the yarn increased linearly with increase of its length. Significant change of electrical resistivity is observed when twist and tensile strain are imparted in the yarn structure. Microscopic image analysis evidences that there is uniform distribution of polypyrrole polymer on the surface of cotton fibres. This electro-conductive yarn is found suitable for thermo-electric See beck effect.

Keywords: Electrical resistivity; *In Situ* chemical polymerization; Polypyrrole; Seebeck effect; Thermo-Electric

Introduction

Research on electro-conductive textiles prepared from conductive polymers such as polypyrrole, polyaniline, polythiophene etc. has been increased in the recent years due to their high potential applications in different fields [1,2]. Obtaining electrical conductivity in the textile materials by metal coating or incorporating metal wires into the textile materials are common practice [3-5]. Also, now-a-days metal fibers are used during staple spinning to manufacture electro-conductive yarns [6-8]. These yarns are used in weaving or knitting to produce electro-conductive fabrics. But naturally the processing of these yarns or fabrics is difficult and they lose the textile properties. Many such limitations associated with processability, low mechanical strength and poor flexibility can be successfully overcome by coating/applying conducting polymers on strong and flexible textile substrates [1,9-11]. Conductive polymers, used to fill or coat fibers, show electrical properties due to their conjugated double bond chain structures [12]. Polypyrrole has been mostly used polymer due to its high conductivity, low toxicity, commercial availability and high stability in air compare to other conducting polymers [10]. Polypyrrole is successfully coated on different textile fibres such as cotton, wool, silk, polyester etc. and their various applications are explored by different researchers [9-13]. So, the trend is of making conductive textiles by coating conductive polymer and characterizing their functional properties to meet demand of technical applications. This research is conducted on the preparation and characterization of electro-conductive cotton yarn prepared from in-situ oxidative chemical polymerization of pyrrole for novel applications.

Experimental

Materials and chemicals

Cotton yarn of liner density 30° Ne is used as substrate. The unit Ne is the English cotton count in indirect system. Ne is defined as the amount of skein material measured in hanks (840 yards) needed to create mass of 1 pound. The chemicals used are sodium hydroxide, pyrrole (Doon Chemicals & scientific Co., India), FeCl₃ (Qualigens Fine Chemicals, India), and *p*-Toluene Sulphonic acid (*p*TSA) Monohydrate (sd fine-chem Ltd., India). All the chemicals used are of laboratory grade and they are used as received.

Preparation of electro-conductive yarn by *in situ* chemical polymerization

Yarns sample is first scoured with 3 gpl sodium hydroxide at 70°C

for 1 h, keeping the material-to-liquor ratio as 1:40. Then a two-step polymerization of pyrrole onto the yarns is followed. In the first step, the dried scoured yarn is immersed into 0.5 M pyrrole solution at room temperature for 20 min. In the second step, the pyrrole-enriched yarn is immersed into oxidant (1M FeCl₃ and 0.02 M *p*TSA) solution so as to initiate polymerization onto the yarns at 5°C for 20 min. In both the steps material-to-liquor ratio was kept 1:40 and 5 g yarn is used in each experiment. After polymerization the color of the yarn is changed to greenish black which is the colour of polypyrrole. After polymerization yarn is washed thoroughly with deionized water and dried in an oven at 60°C for 120 min.

Measurement of electrical resistivity of electro-conductive yarns

The electrical resistivity is measured as resistance per unit length of the yarn. In this study both electrical resistance (k Ω) and resistivity (k Ω m⁻¹) of the yarns has been measured. The electrical resistance of the electro-conductive yarns is measured at different lengths of the yarns using the two-probe test technique at a constant load of 75 g-force on the yarns. The resistance is measured by a digital Multimeter (MASTEC* MAS830L). The measurement is carried out at 25 \pm 2°C temperature and 65% relative humidity.

Measurement of electro-mechanical property of electroconductive yarns

The electro-mechanical property of the polypyrrole coated electroconductive yarn is evaluated by using the Instron tensile tester model 4301, at a gauge length of 250 mm and the traverse speed of 50 mm s⁻¹. The two ends of the yarn near to the jaws are connected respectively, to the two probes of a digital multimeter for recording the electrical resistance. The effect of strain on electrical resistance is studied by moving the upper jaw at the traverse speed mention above. This test was carried out at $25 \pm 2^{\circ}$ C temperature and 65% relative humidity.

*Corresponding author: Subhankar Maity, Department of Textile Technology, Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, Punjab-144011, India, Tel: 9878177967; E-mail: maity.textile@gmail.com

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Measurement of effect of twist on electrical resistance

A fixed measuring length of 10 inch yarn is taken and the initial twist is measured by using Paramount twist tester. After that both end of the fresh length of yarns are fixed to the twist tester, one end at fixed jaw and other end at the rotating jaw. Also extreme end points are connected with positive and negative terminal of digital multimeter by crocodile clip for resistance measurement as shown in Figure 1. The rotating jaw is rotated manually and hence the twist in the yarn gradually increased. Final twist per inch of the yarn can be calculated by dividing total final twist (which is equals to the sum of initial twist and applied manual twist) to the measuring length (10 inch). The change of resistance with increment of twist is measured by multimeter. This is carried out at $25 \pm 2^{\circ}$ C temperature and 65% relative humidity. The resistances versus twist per unit length data of the electro-conductive yarns are plotted.

Measurement of thermo-electric effect of polypyrrole coated cotton yarn

Polypyrrole coated electro-conductive yarns of 30 cm length and copper wires of 50 cm length are taken for preparing thermocouple. Yarn is connected properly with two copper wires at both ends. These joint ends act as junctions. The other ends of copper wires are connected to a micro-volt meter for measurement of generated emf. Water bath is used to create temperature difference between two junctions as shown in Figure 2.

Image analysis by optical microscope

The surface deposition of electro-conductive polypyrrole is analyzed by taking the surface image of the treated yarn in Nicon Eclipse E200 optical microscope. The magnification was 20X in case of fibres and that of 4X in case of yarn.

Results and Discussions

Electrical resistivity of poypyrrole coated cotton yarn

It is found that polypyrrole add-on is about 11.6% and the mean resistivity of yarn is about 182.63 K Ω /m⁻¹. The effect length on electrical resistance of electro-conductive yarn is shown in Figure 3. Linear regression equation has been fitted with data obtained from measurements. The equation and value of the coefficient of determination (R^2) are shown. Almost liner relationship is observed between yarn length and resistivity with R^2 value of 0.9630.

Effect of twist on electrical resistance yarn

It is observed that as twist is imparted in the polypyrrole coated yarn the electrical resistivity gradually decreases. So, a negative correlation is there between yarn twist and electrical resistance and results have been shown in Figure 4. Linear regression line has been fitted with all data. This behavior of the yarns may be suitable for application as a sensor.

Effect of tensile strain on electrical resistance yarn

The electro-mechanical behaviors of polypyrrole coated electroconductive yarn is evaluated and shown in Figure 5. It can be seen that the electrical resistivity yarn is decreasing with increasing tensile strain. As the strain increases fibres are compacted and aligned along the yarn axis. As a result polymer to polymer contacts increases which help to easy charge transfer along the polymer chain resulting low resistivity.

Thermo-electric effect of polypyrrole coated cotton yarn

Polypyrrole coated textile yarn is coupled with copper wire and a thermocouple is fabricated. Thermo-electric effect of this thermocouple is studied and result is shown in Figure 6. As the temperature difference between hot and cold junction increases more emf is generated and this behavior follows a polynomial trend.



Figure 4: Effect of twist on electrical resistance of polypyrrole coated varn



coated yarn.





polypyrrole coated cotton fibres (20X) and (c) polypyrrole coated cotton varn (4X).

Image analysis of polypyrrole coated cotton yarn

Microscopic images of untreated fibres, Polypyrrole coated fibres and yarn are shown in Figure 7. It can be seen that fibres of untreated yarn have convolutions, clear surface and transparent. In case of polypyrrole coated fibres and yarn their color turned to black, what is the color of polypyrrole polymer. This proofs that polypyrrole is present on the surface of fibres and its distribution on fiber surface is quite uniform.

Conclusions

Electro-conductive cotton yarn is successfully prepared by in situ oxidative chemical polymerization of pyrrole in aqueous solution. The mean resistivity 16 Ne yarn is obtained about 182.63 $K\Omega/m^{\text{-1}}$ with 11.6% polypyrrole add-on. If the twist is imparted in yarn stucture, resistivity is decreased linearly. A negative correlation between tensile strain and resistivity of the yarn is found. So the resistivity of the yarn is significantly depended upon the yarns twist and applied strain. This characteristic of the yarn is suitable for application of the yarn used as sensor. A polynomial trend of thermo-electric emf generation is observed in thermocouple prepared with this yarn coupled with copper wire.

References

- Kuhn HH, Child AD, Kimbrell WC (1995) Toward Real Applications of Conductive 1. Polymers. Synthetic Metals 71: 2139-2142.
- Devaux E, Koncar V, Kim B, Campagne C, Roux C, et al. (2007) Processing & 2. Characterization of Conductive Yarns by Coating or Bulk Treatment for Smart Textile Applications. Transactions of the Institute of Measurement & Control 29: 355-376
- 3 Cheng KB, Lee ML, Ramakrishna S (2001). Electromagnetic Shielding Effectiveness of Stainless Steel/Polvester Woven Fabrics. Text Resea Journ 71: 42-49
- 4. Perumalraj R, Dasaradan BS (2011) Ellectroless Nikel plated Composite Textile material for Electromagnet compatibility. In J Fibr Text Resea 36: 35-41.
- Zhang H, Tao X, Wang S, Yu T (2005) Electro-Mechanical Properties of Knitted Fabric Made From Conductive Multi-Filament Yarn Under Unidirectional Extension, Text Resea J 75: 598-606
- Knittel D, Schollmeyer E (2009) Electrically High-Conductive Textiles. Synthetic 6 Metals 159: 1433-1437
- Schwarz A, Kazani I, Cuny L, Hertleer C, Ghekiere F, et al. (2011) Comparative Study on the Mechanical Properties of Elastic, Electro-Conductive Hybrid Yarns & Their Input Materials. Textile Research Journal 81: 1713-1724.
- Schwarz A, Kazani I, Cuny L, Hertleer C, Ghekiere F, et al. (2011) Electro-Conductive & Elastic Hybrid Yarns - The Effects of Stretching, Cyclic Straining & Washing On Their Electro-Conductive Properties. Materials & Design 32: 4247-4256
- 9 Maity S, Chatterjee A, Singh B, Singh AP (2014) Polypyrrole based Elelctro-Conductive Textiles for Heat Generation. The Journal of the Textile Institute 105 887-893

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- Maity S, Chatterjee A (2013) Preparation and Characterization of Electroconductive Rotor Yarn by In situ Chemical Polymerization of Pyrrole. Fibers and Polymers 14: 1407-1413.
- Malhotra U, Maity S, Chatterjee A (2014) Polypyrrole-Silk Electro-Conductive Composite Fabric by In Situ Chemical Polymerization. J Appl Polym Sciec 132.
- 12. Najar SS, Kaynak V, Foitzik CR (2007) Conductive wool yarns by continuous vapour phase polymerization of pyrrole. Synthetic Metals 157: 1-4.
- Dave J, Kumar R, Srivastava HC (1987) Studies on modification of polyester fabrics I: Alkaline hydrolysis. J Appl Polym Scie 33: 455-477.