DEVELOPMENT OF THE FORCE SENSITIVE RESISTORS USING POLYPYRROLE COATED COTTON WOVEN FABRIC FOR PRESSURE SENSING APPLICATION

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Abstract

The cotton twill woven fabric is taken for coating with polypyrrole (PPy) conductive polymer by chemical oxidation method. Monomer, oxidant and dopant used are pyrrole, ferric chloride and Tetra-ethyl ammonium p-toluene-sulfonate at ratio of 4:2:1. Optimized monomer concentration of 0.4M is taken for polymerization process and processing time of 4 hours at 15 ºC. After the polymerization, the samples were washed with 2% ethanol and distilled water simultaneously until excess particle removing. The pressure sensing ability of the PPy cotton fabric is measured with change in resistivity by varying weight. The warp direction of the fabric is showing good sensitivity than weft direction. PPy cotton fabric has better sensing ability of pressure compare with standard nonwoven sample.

Key words

Cotton, Polypyrrole, Chemical oxidation, Resistivity, Woven, Nonwoven.

1. INTRODUCTION

Conductive polymers have attracted the attention of a great number of researchers in the textile field due to their potential applications in composites with natural, artificial or synthetic fibers. The affinity to several kinds of fibers, yarns and fabrics with doped conjugated polymer, permits the production of composite textiles with improved electrical properties. Polypyrrole (PPy) is one of the most suitable conductive polymers for deposition on textile materials due to its excellent conductivity and relevant environmental stability [1]. PPy is commonly produced by electrochemical synthesis or chemical oxidative polymerization in aqueous solution and shows good affinity with natural and artificial fibers. Textile substrates can be easily covered with a PPy layer by immersion of the fabric in the polymerization solution containing pyrrole, an oxidant and a doping agent [2].

The force sensing resistors (FRS) are developed for precise pressure sensor applications. The FSR is working with measuring the change in resistance by increase in force. It detects physical pressure, squeezing and weight by change in resistive value. The applications of FRS are in medical field [3], shoe insoles to detect pressure of our foot [4], video games, electrical automobiles, sporting equipments, etc, [5]. The textile spacer fabrics coated by silver on both side act as a capacitor, whose capacitance helps to measure snowboarding sock pressure during skiing [6]. Highly elastic fabric was coated with polypyrrole (PPy) polymer to measure strain in urinary bladder of urinary dysfunction. The resistance is influenced by stretching the fabric and measure strain variation [7]. Conductive PPy coated electrospun poly (vinylidene fluoride) (PVDF) fiber mat is developed for pressure sensor application; the compression stress is significantly changing the relative conductivity of PVDF/PPy mat [8].

2. EXPERIMENTAL

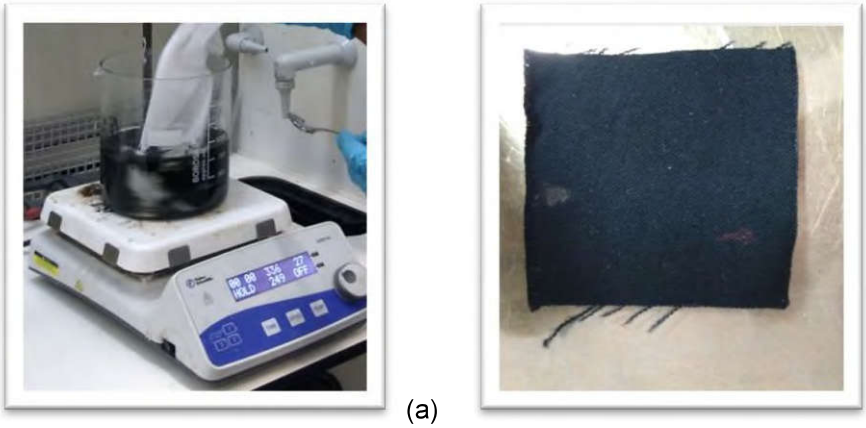
2.1. Materials

The pyrrole monomer is purchased from Sigma Aldrich. Ferric chloride from Sigma Aldrich is used as an oxidising agent, Tetra-ethyl ammonium p-toluene-sulfonate as a doping agent from sigma Aldrich and distilled water was used through the process as a solvent. The cotton woven twill white fabric with specification of 277 grams per square meter (GSM) and 0.71 mm thickness was taken for the process.

2.2. Methods

The pyrrole monomer was polymerised by chemical oxidation method with ferric chloride as oxidizing agent and tetra-ethyl ammonium p-toluene-sulfonate as doping agent. The optimized molarity of monomer was taken for the experiment is 0.4 M [9]. Temperature maintained through-out the process is 15 ^{o}C and processing time is 4 hours.

In figure 1(a) shows the experimental setup and figure 1(b) shows the image of the cotton sample coated with polypyrrole polymer. Cotton woven fabric was taken and weigh in digital balance was measured to note weight of material. Then 1:40 material to solvent ratio was taken, distilled water is used as a solvent. After that, the monomer, oxidant and dopant were taken in the ratio of 4:2:1 and mixed in solvent under fume hood. Magnetic stirrer was used to dissolve the chemicals at 700 rpm for 10 minutes. Once the chemicals were dissolved then the fabric sample was dipped in the bath and continuously stirrer for 4 hours at 700 rpm in 15 ^{o}C throughout the process. After 4 hours the samples were removed from the bath and washed in 2% ethanol solution for several times and again washed with distilled water until the excess particles were removed from the surface of the sample. Finally, the sample was dried in the hot air oven for 1 hour at 80 ^{o}C temperature. For further analysis, the dried samples were conditioned for 24 hours at laboratory atmosphere.



(a) (b)

Figure 1. (a) Experimental setup and (b) image of cotton fabric coated with polypyrrole polymer.

3. RESULTS AND DISCUSSION

Figure 2 shows the photographic image of the force sensitive resistor test setup with sample. In this setup, the sample was holds by connecting rods on both ends at 4 cm distance; insulation material is placed on the sample for separating the weighing material (Coins were used for weight) and multi-meter is connected on the rods to measure the resistance at different pressure.

For comparison of the pressure sensing capability, the developed conductive cotton sample was compared with the market sample. The market sample was brought from Adafruit, it was a nonwoven fabric filled with conductive material and the specifications are 170 GSM, resistivity of 20 Ohm /sq., 0.6 mm thickness and polyester/ nylon 6 filament blend ratio of 70:30 [10].

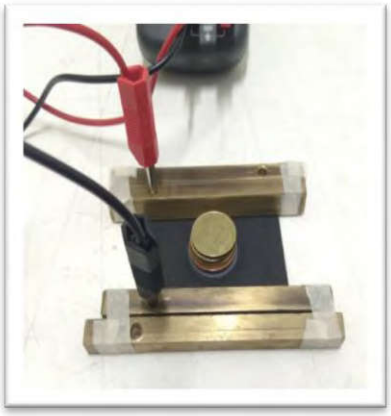


Figure 2. An image of the force sensitive resistor setup.

The force sensitive resistor test results are shown in figure 3 and 4 for standard nonwoven fabric and PPy coated cotton woven fabric respectively. The pressure sensing ability is measured in resistance with respect to varying weights. Linear regression analysis is used to compare the test results by graphically. The machine direction (MD) is showing very good correlation than Cross direction (CD) in nonwoven standard sample. PPy coated cotton fabric shows that warp direction has better sensing ability than weft direction with help of correlation value.

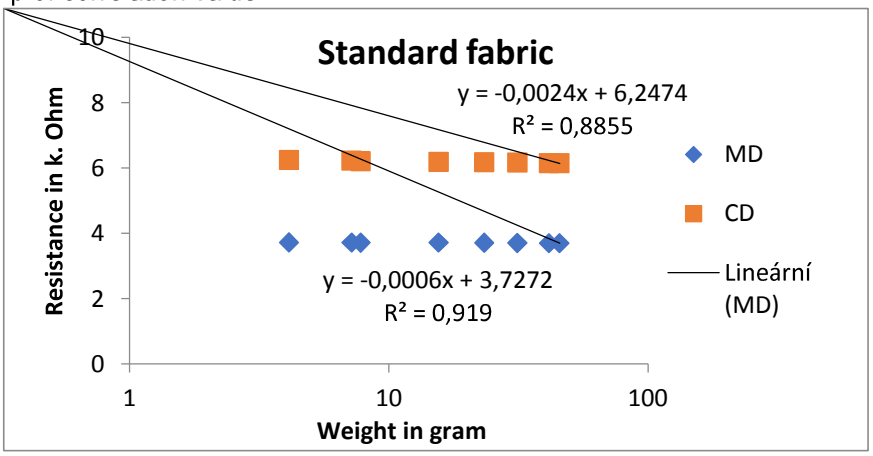


Figure 3. Graph of resistance [Ω] versus weight [gram] of standard nonwoven fabric with linear regression analysis.

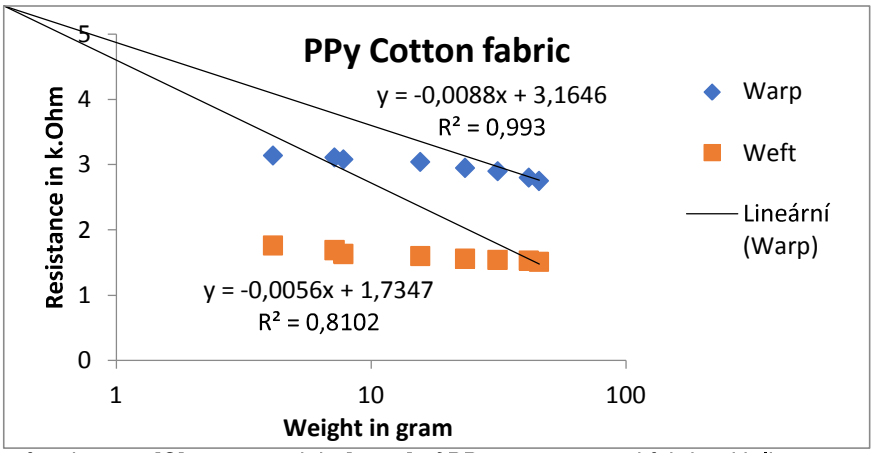


Figure 4. Graph of resistance [Ω] versus weight [gram] of PPy cotton coated fabric with linear regression analysis.

The coefficient of determination R^2=0.99 for PPy coated cotton fabric in warp direction and R^2=0.92 for standard nonwoven fabric in machine direction (MD). The coefficient of determination shows that the PPy coated cotton fabric is more sensitive with respect to force applied on sample.

4. CONCLUSIONS

The optimized pyrrole monomer concentration of 0.4M is used to coat the cotton woven fabric and the coating of polypyrrole looks evenly coated on the surface of the fabric (Figure 1.). The eight different weights were used to measure the resistivity change on the samples. For standard nonwoven fabric, the change in resistance with respect to weight is good in both MD and CD but MD shows the very good sensitivity and the coefficient of determination R^2=0.92 in MD compare with R^2=0.88 in CD shows there is no significance. PPy cotton fabric has coefficient of determination R^2=0.99 in warp direction and R^2=0.81 in weft direction. Hence, the warp direction is having more sensitive to applied pressure than weft. Overall, the PPy cotton fabric is having very good sensitivity to pressure that the standard fabric.

ACKNOWLEDGEMENTS

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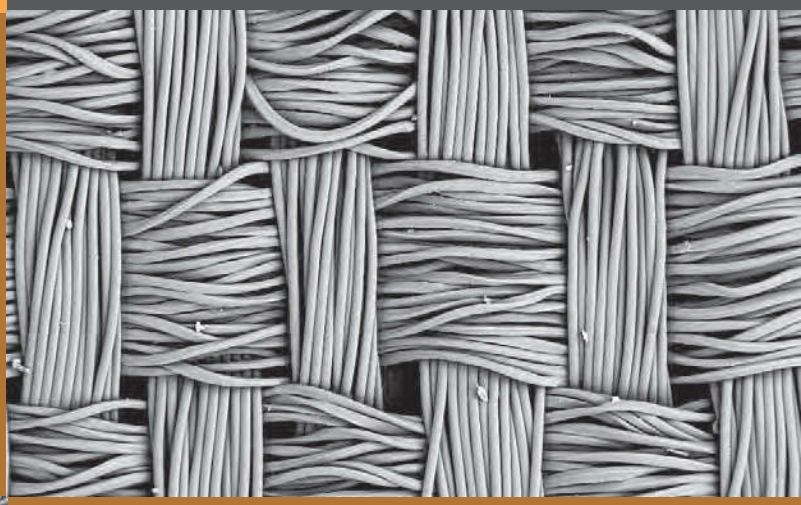

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