www.dergipark.gov.tr
ISSN:2148-3736
El-Cezerî Fen ve Mühendislik Dergisi
Cilt: 5, No: 2, 2018 (310-315)

El-Cezerî Journal of Science and Engineering
Vol: 5, No: 2, 2018 (310-315)

ECJSE

Research Paper / Makale

Resistive Pressure Sensing Behavior of Electrically Conductive PEDOT:PSS-Nonwoven Fabric Composites

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Received/Geliş:03.01.2018 **Revised/Düzeltme:**16.02.2018 **Accepted/Kabul:** 16.02.2018

Abstract: Wearable electronic textiles have become increasingly important in daily life. Such garments are based on sensors that are distributed on the human body. These sensors should be comfortable and fit for the aim of the wearer. In general, these textiles have been used for pressure, stretch and temperature sensors. In this study, electrically conductive nonwoven fabrics were prepared by Drop Casting-Drying method and their pressure sensing behavior was investigated.

Keywords: Conductive Textile, PEDOT:PSS, Pressure Sensor

Elektriksel İletken PEDOT:PSS Kaplı Nonwoven Kumaş Kompozitlerinin Rezistif Basınç Sensör Davranışı

Öz: Giyilebilir elektronik tekstiller günlük yaşamda giderek daha çok önemli hale gelmektedir. Böyle giysiler, insan vücudu üzerine dağıtılan sensörlere bağlıdır. Bu sensörler, giyen için konforlu ve amaca uygun olmalıdır. Genelde bu tekstiller basınç, germe ve sıcaklık sensörleri için kullanılmaktadır. Bu çalışmada, elektriksel olarak iletken nonwoven kumaşlar Drop Casting-Drying metodu yoluyla hazırlanmış ve basınç sensör davranışları araştırılmıştır.

Anahtar kelimeler: İletken Tekstil, PEDOT:PSS, Basınç Sensörü

1. Introduction

Electronic textiles (e-textiles) are the integration of textiles and electrics-electronics technologies which can be used in military, sports, fashion and healthcare applications. The main purpose of e-textiles is to find solutions to the general issues encountered daily and to ease the daily life. Pressure sensors are one of the main application area of e-textiles and can be used in orthotics, sports and rehabilitation products. The production of conductive fabric based pressure sensors is a key area of smart textiles due to their significant final characteristics such as flexibility, lightness, conductivity and process ability [1]. The textile based flexible capacitive, piezoresistive and piezoelectric pressure sensors can be developed by different techniques. However the resistive type fabric pressure sensors have some advantages with respect to excellent sensitivity and stability, repeatability, easy design and lower energy consumption [2]. The pressure sensor fabrics are coherent with the integration of them on garments and essential for smart textiles to become available. The transformation of fabric to a pressure sensor increase the garment functionality and

How to cite this article
Çetiner, S., Köse, H., "Resistive Pressure Sensing Behavior of Electrically Conductive PEDOT:PSS-Nonwoven Fabric Composites" El-Cezerî Journal of Science and Engineering, 2018, 5(2); 310-315.

Bu makaleye atıf yapmak için
Çetiner, S., Köse, H., "Elektriksel İletken PEDOT:PSS Kaplı Nonwoven Kumaş Kompozitlerinin Rezistif Basınç Sensör Davranışı" El-Cezerî Fen ve Mühendislik Dergisi 2018, 5(5); 310-315.

gain advantage in smart textile applications [3]. In literature, the method used in this study is called Drop Casting-Drying Method [4]. Some of the advantages of this method are easy process, less material waste and less environmental pollution. In this study, PEDOT:PSS coated nonwoven composite fabrics were produced by drop casting method and their pressure sensing behaviors were investigated.

2. Experimental

2.1. Materials

PEDOT:PSS dispersion (PH 1.5-2.5) was supplied from Sigma Aldrich and DMSO was supplied from Merck. They were used as received. Polypropylene based hydrophilic Nonwoven fabrics were obtained from Teknomelt (Kahramanmaraş, TURKEY). Nonwoven fabric selected in this study was a Spunbond-Meltblown-Spunbond (SMS) with a weight of 330 gr/m^2.

2.1. Fabrication of Electrically Conductive Polypropylene Nonwoven Fabric

The process is illustrated in Figure 1. The 4 cm x 4 cm nonwoven fabric was washed with and distilled water for 20 minutes and was dried for 20 min at 80 ^{o}C before the coating process. The PEDOT:PSS coated nonwoven fabric was showed in Figure 2. Polymerization was performed in a beaker by mixing with 20 ml DMSO and 600 µl PEDOT:PSS at 25 ^{o}C for 30 min. The homogeneous PEDOT:PSS-DMSO solution was transferred to a syringe and dropped on nonwoven fabric up to 4 drops. The PEDOT:PSS-nonwen fabric was dried for 2 hours at 125 ^{o}C. The polymerization cycle was repeated for 4 times to achieve higher electrical conductivity [4].

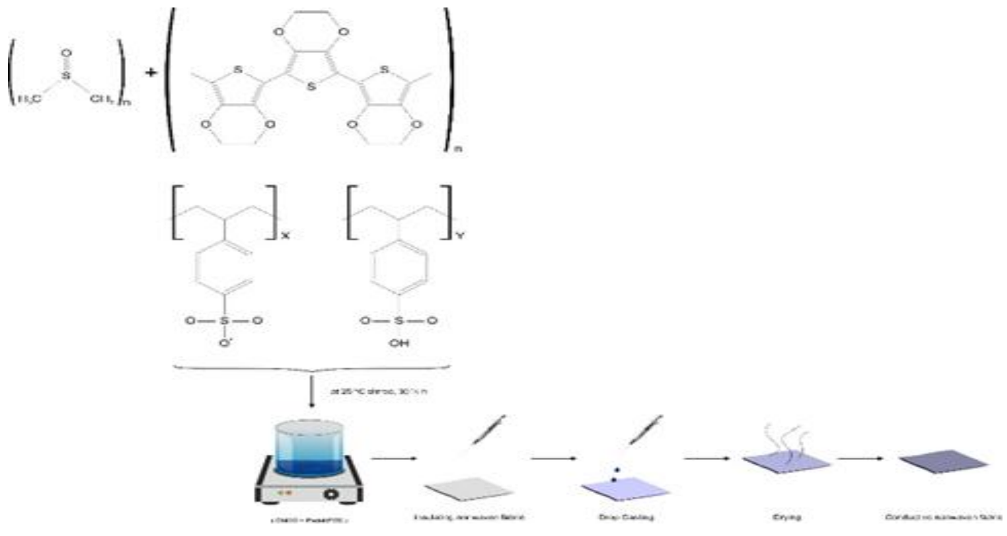

Figure 1. Preparation of solution and stages of Drop Casting

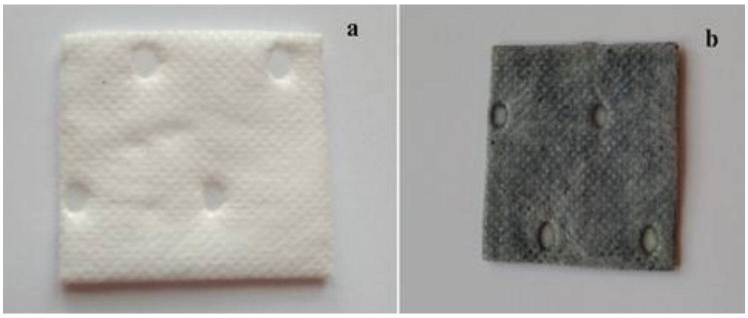

Figure 2. a) uncoated nonwoven fabric, b) PEDOT:PSS coated nonwoven fabric

nonwoven fabric

2.3. Characterization of Composite Fabrics

Fourier Transform-Infrared (FT-IR) spectrophotometric analysis for PEDOT:PSS-coated nonwoven fabrics was obtained by using a Perkin Elmer Spectrum One.

2.4. Coating Thickness and Surface Resistivity of PEDOT:PSS Coated Polypropylene Based Nonwoven Fabric

The amount of PEDOT:PSS coating on nonwoven fabric, A (%), was expressed by using the following equation:

$$A(\%)=((W_2-W_1)/W_1)\ x100 \qquad (1)$$

Where W_2 is thickness of the PEDOT:PSS-coated nonwoven fabric and W_1 is thickness of the uncoated nonwoven fabric. The amount of PEDOT:PSS inset to the fabrics is expressed as percentage of weight increase indicated by the following equation:

$$\%\ Weight\ increase = (M_A - M)/M\ x\ 100 \qquad (2)$$

Where M is the first weight of the provisory fabrics, and M_A is the weight after PEDOT:PSS deposition, drying, and conditioning. The surface resistivity of composite fabrics was measured by a digital multimeter. Weight and thickness values of composite nonwoven fabrics were showed in Table1.

Table 1. Weight and thickness values of PEDOT:PSS-Polypropylene Nonwoven Fabrics

Parameter	**Uncoated Nonwoven Fabric**	**PEDOT:PSS coated Nonwoven Fabric**	**Increase (%)**
Weight (g/m^2)	330	479	45,15
Thickness (mm)	1,519	1,796	18,23

2.5. Pressure Sensing Behavior

Pressure sensitivity is defined as the ability of the material to change resistance as a result of mechanical pressure applied to the material. This effect is directly related to the change in polarization intensity within the material. If a force is applied to a material with permanent polarization, the distance between the poles decreases, the charge accumulates on the surface, and when combined with a conductor, current flows [5], as shown in Figure 3.

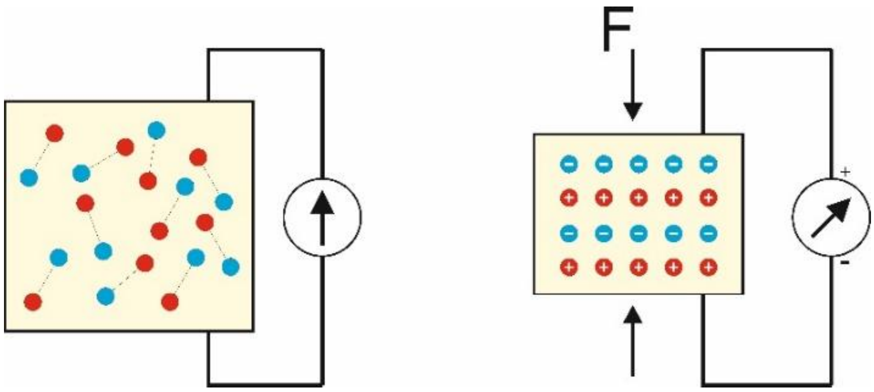

Figure 3. Transforming into electrical magnitude of the mechanical effect [5].

3. Results

3.1. Fourier Transform Infrared (FTIR) Spectrophotometric Analysis

Figure 4 presents the FTIR spectra of uncoated and PEDOT:PSS coated nonwoven fabrics.

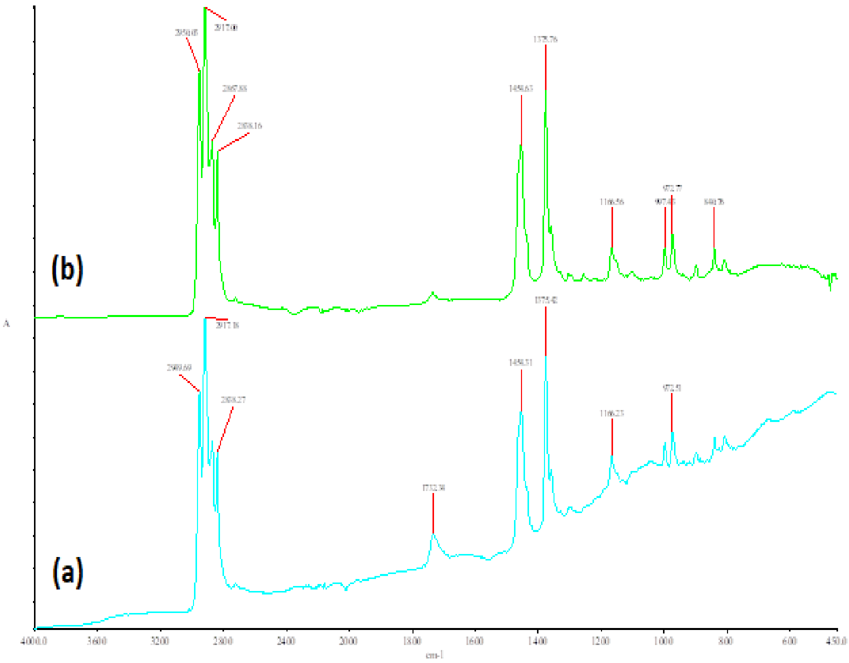

Figure 4. FTIR plots of pristine fabric (a), PEDOT:PSS-PP nonwoven fabric (b)

The IR characteristic peaks of PEDOT:PSS have not been followed exactly. Any of peak after PEDOT:PSS coating have not appeared due to less amount of PEDOT:PSS in PP nonwoven composite structure. The absorbance values of existing IR peaks have increased after drop casting of PEDOT:PSS in composite structure, as shown in Figure 4. In uncoated PP nonwoven fabric, the absorbance bands were observed as: 972-997 cm^{-1} ($–CH_2$ rocking vibration), 1167 cm^{-1} ($–CH_3$ anti-symmetric deformation), 1455 cm^{-1} ($–CH_2$ symmetric deformation), 1167 cm^{-1} ($–CH_3$ symmetric deformation), 1167 cm^{-1} (–CH anti-symmetric deformation) and 2917 cm^{-1} ($–CH_3$ symmetric stretching) [6]. Figure 4a illustrates the FTIR spectrum of PEDOT:PSS coated PP Nonwoven composite fabric. The absorption bands were determined at 1161 cm^{-1} and 1065 cm^{-1} (C–O–C stretching of PEDOT:PSS). Furthermore, peaks at 1375 & 1454 and 1732 cm^{-1} were related to carbon double bonds (C = C) in the PEDOT:PSS coated PP nonwoven composite structure [7,8].

3.2. Resistive Pressure Sensing Behavior of PEDOT:PSS coated Nonwoven Fabric Composites

In resistive pressure sensor measurement principle of conductive polymeric fabrics, when a pressure is applied, the electrical conductivity of conductive fabrics increases because of the conductive nanoparticle distributions, composing the electrically conductive pathways. When the pressure is set free, the conductive networks are ceased, and the conductivity is turned back to the original value [9,10]. To demonstrate the resistive pressure sensing behaviour of PEDOT:PSS coated nonwoven fabric composite, a conductive polymer based sensor fabric which react to pressure was produced by locating of two copper electrodes on the top and at the bottom of a PEDOT:PSS-PP nonwoven fabric. When a pressure was applied, the surface resistivity of the fabricated sensor changed and the relationship between the resistivity and the pressure exerted on the PEDOT:PSS coated PP nonwoven fabric sensor was measured, as shown in Figure 5.

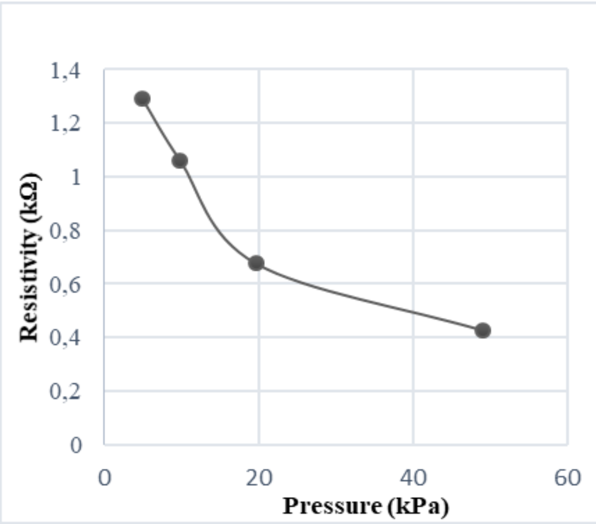

Figure 5. Resistivity performance of pressure sensor from PEDOT:PSS-PP nonwoven fabric depending on applied pressure.

The surface resistivity of PEDOT:PSS-PP nonwoven composite fabric decreased with the increase of applied pressure which showed a candidate for pressure sensor fabrics, as shown in Figure 5.

4. Conclusion

In this study, PEDOT:PSS coated nonwoven composite fabrics were produced by drop casting method and their pressure sensing behaviors were investigated. The IR characteristic peaks of

PEDOT:PSS were not followed exactly. The absorbance values of existing IR peakswere increased after drop casting of PEDOT:PSS in composite structure. The surface resistivity of PEDOT:PSS- coated nonwoven fabrics decreased with the increase of applied pressure which showed a candidate for pressure sensor fabrics.

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