Study of Conductivity Behavior of Nano Copper Loaded Nonwoven Polypropylene Based Textile Electrode for ECG

Tasnim N. Shaikh, Satyajeet Chaudhari, B. H. Patel, Megha Patel

Abstract- ECG technique is employed in medical science for measuring electrical activity of the heart. This technique often criticized for skin irritation due to the wet gel media applied on the body. The condition becomes more crucial for long-term monitoring. Wet electrodes need to be replaced with dry one and in that disposable form. Textile electrode is a potential choice for the purpose. Many reports are also available where knitted and woven polyester, nylon; cotton and acrylic fabrics were used as conductive electrode. The desired conductivity was imparted by conductive material surface treatment for woven or using conductive steel filaments in knitted. But due to higher stiffness they sound uncomfortable on use. The present research therefore designed to develop highly conductive textile material with better comfort properties. Polypropylene nonwoven fabric, a most versatile, economical and highly preferred base material in medical textile is used for the purpose. It is loaded with different concentrations of copper Nano particles. The prepared polypropylene nonwoven fabric was then characterized using polarized microscope and FTIR technique. The electrical conductivity of copper loaded textile was measured by Precision Multimeter 8846A tester. Better conductivity is observed with increased deposition.

Keywords- Electrocardiogram, FTIR, Conductivity, polypropylene, Nano particles.

I. INTRODUCTION

Over past few years, number of wearable physiological monitoring systems have been developed for health monitoring of patients in hospitals and real-life situations. The wearable sensing systems help in providing an early detection of pathological signs and improving the curative rate of disease without disturbing the patient's daily life [1-17, 25]. The electrocardiogram is a primary diagnostic tool for recording the electrical activity of heart over a period of time, as detected by electrodes attached to the surface of skin and recorded by a device, external to the body. It picks up electrical impulses generated by the polarization and depolarization of cardiac tissue and translates into a waveform.

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Hence it consists of three main parts: QRS-complex, P-wave and T-wave. They are used to measure the bio-potential signals. Bio-potentials are electrical potentials in the human body, where Cl^-, Ca+, and Na+ ions transport charges in an organic system, in contrast to electrons in the leads of a sensing device. In order to measure these bio-potentials, the ion currents in the body have to be changed to electron currents in the electrode [2, 18].

II. COMMERCIAL ELECTRODES

Disposable Ag/AgCl electrodes are most commonly used today in ECG measurements. The outer layer of the skin has a dry dielectric layer, called the stratum corneum. This will cause reduction of the transfer mechanism from ions to electrons. The Ag/AgCl electrode cannot be used directly on the skin, and hence is used as a wet electrode with the help of a conduction gel that moisturizes the skin outer layer and makes it highly ion conductive. Despite of having advantages of Ag/AgCl electrode, it is not ideal for long term monitoring, furthermore this electrode is applied with the wet or conduction gel, which dehydrates gradually during usage, affects the signal quality. The skin preparations and gel applications many a times also cause some skin allergies such as skin irritation, dermal inflammation and other skin problems, causing the patient discomfort [18].

III. TEXTILE ELECTRODES

Textile structural materials as an ECG electrode are fairly a new concept. Normally the textile electrodes are made by weaving, knitting or embroidering conductive yarn to the structure. The conductive yarn can be silver coated yarn or metal filaments braided into yarn. The textile materials are usually synthetic for example polyester or polyamide. They endure very well abrasion, absorb a very little moisture and dry fast. Compared to commercial Ag/AgCl electrode, textile electrodes are flexible and stretchable. They can fit well to the skin contour, thus improving skin electrode contact and also suitable for long-term monitoring. Moreover these electrodes do not require any application of conduction or wet gels, hence do not impart any skin problems [1, 24]. However, they suffer from two major draw backs;

i) Higher cost and
ii) Uncomfortable due to added stiffness of conductive yarn[1, 19]

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IV. AIM OF THE STUDY

Present research deals with the development of a highly conductive textile material by using highly conductive Nano particles. Such electrode will offer advantages over conventional ones;

i. Nano particles can provide high durability for treated fabrics. As they possess large surface area and high surface energy. These ensure better affinity for fabrics and lead to an increase in durability of the textile functions.

ii. Since consumption of conductive matter is less, cost of electrode will reduce considerably without having adverse impact on its performance.

iii. The Nano treated material has almost no change in stiffness as Nano material is reinforced in the structure in a very negligible quantity [20].

Polypropylene nonwoven fabric is the most versatile, economical and highly preferred base material for various medicinal purposes. In addition it is the lightest of all synthetic and natural fibers, having better stability than other synthetic materials, absorbs a very little moisture and dries fast, even ductile and washable. So, it is preferred as base material for the study [26].

V. MATERIALS

Rectangular pieces of 4cm x 6cm polypropylene nonwoven with 119.44gsm (gram per square meter) were used as base material. They were loaded with different concentration Nano solution of copper, made by Cupric Sulphate ($CuSO_4.5H_2O$) and Sodium Borohydride ($NaBH_4$) of AR grade. These chemicals were supplied by Durga Fine Chemicals Ltd.

VI. METHODS

Particles of copper in copper oxide form were prepared inside the polymer matrix or polypropylene web by reducing Cupric Sulphate into copper oxide by Sodium Borohydride as reducing agent, using a simple multi-dip technique. The entire process was carried out under atmospheric conditions at room temperature. Different concentrations of chemicals were used for multi-dip technique to synthesize copper Nano particles inside the nonwoven web. These chemicals are prepared by adding different weights of components in 100ml distilled water (Table 1).

Table 1: Sample Details

Sample code	Cupric Sulphtae ($CuSo_4.5H_2O$) (gms)	Sodium Borohydride ($NaBH_4$) (gms)
Pp	0.0	0.0
Pc_1	0.1	0.1
Pc_2	0.2	0.2
Pc_3	0.3	0.3
Pc_4	0.4	0.4

VII. TESTING AND ANALYSIS

All the samples loaded with different concentrations of copper Nano particles, including base material were characterized using polarized microscope (ProgRes C3) at 400X and FTIR technique. The electrical conductivity of copper loaded textile as well as base material was measured by Precision Multimeter 8846A tester. Electrical resistance of samples were checked at 2.3 Volts at the gauge of 25 mm as per AATCC Test Methods [21]. The conductivity was calculated by converting the electrical resistance measured on Multimeter by using equation 1. Where electrical resistivity is the product of electrical resistance in ohm and gauge length in meter.

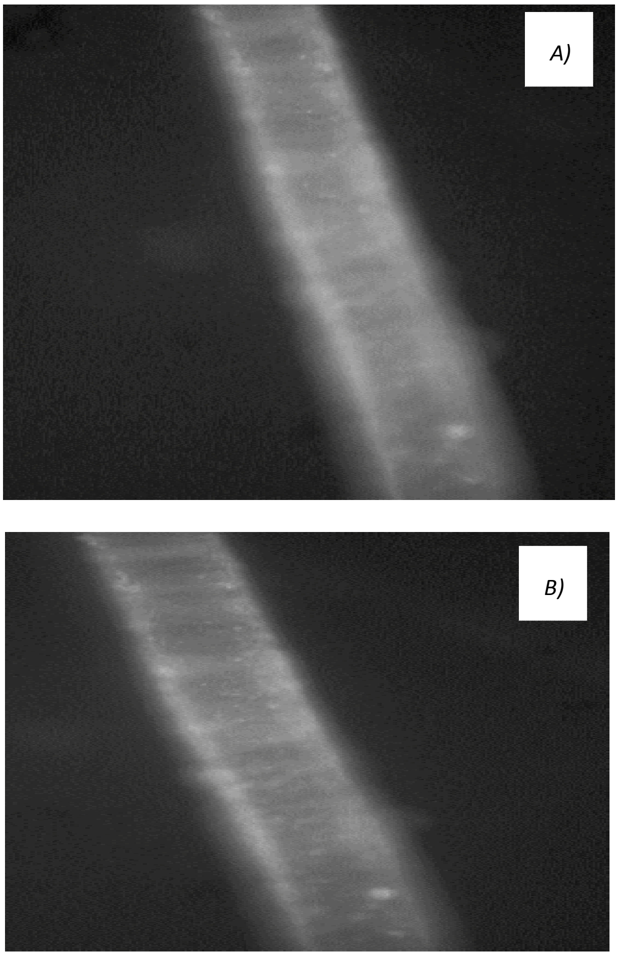
$$\text{Conductivity } (\sigma) = \frac{1}{\text{Electrical Resistivity } \rho(\text{ohm. m})} \ldots\ldots\ldots\ldots [\text{equ. } 1]$$

The chemical compositions of the pure polypropylene and Nano treated fabrics were evaluated using FTIR Spectroscopy, Nicolet IS10 FT-IR Spectrometer (Thermo scientific).

VIII. RESULTS AND DISCUSSION

The microscopic view of treated and untreated fabrics were recorded at the magnification of 400X for all the samples. As per expectation increase in deposition is recorded with Nano concentration. Figure1 represents comparative microscopical views for untreated and treated fabric at highest concentration.

Figure 1: Microscopical views A) Treated, B) Untreated



The chemical compositions of the pure polypropylene and Nano copper treated polypropylene fabrics were evaluated using FTIR Spectroscopy at spectral range of 400cm^{-1} to 4000cm^{-1}. Comparative evaluation is done here between base fabric and highest concentration Nano treated fabric. This can help in signifying the change in spectroscopy sharply. Figure 2, represents the IR characterization

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absorption peak of pure polypropylene fabric, from which it can be seen that the major peaks associated were hydrogen bonded symmetric O-H stretching at 3066 and 3053 cm^{-1}, C-H stretching around 2968 cm^{-1}, asymmetric -CH stretching vibration at 2908 cm^{-1}. C=O stretching is observed at 1743 and 1710 cm^{-1}, asymmetrical CH_2 bending scissoring type around 1452 cm^{-1}, symmetrical C-H bending around 1300 cm^{-1}, the presence of polypropylene is confirmed at 972 cm^{-1} which is irrespective of its tacticity, but at 1174 cm^{-1} it is confirmed that the tacticity of polypropylene polymer is iso-tactic[22]. Some O-H stretch and free vibrations peaks are observed around 3600 cm^{-1}.

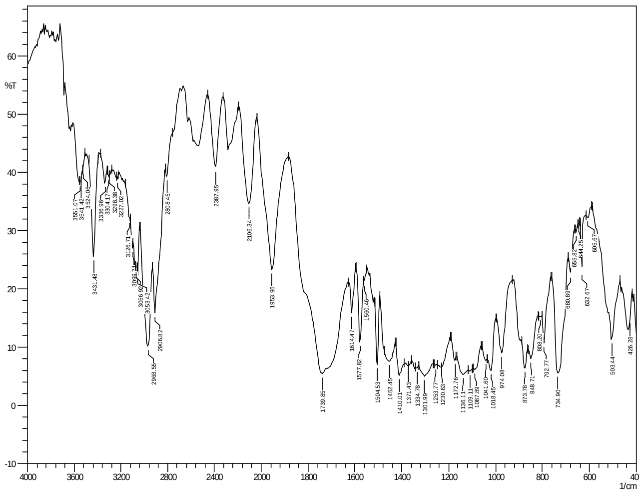

Figure 2 - FTIR Spectrum of Base Polypropylene fabric.

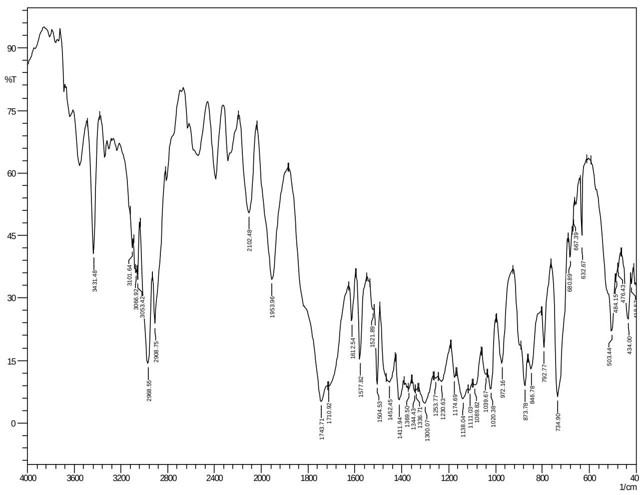

Figure 3 - FTIR Spectrum of Cu Nano treated Polypropylene fabric

Presence of Copper in a polymer can be realized by some of the peaks in the range of 600 to 1000cm^{-1} like at 605, 644, 655, 808 and 848 cm^{-1} [figure 3]. They are mainly attributed to the vibration of the Cu bonds [8]. Electrical conductivity has not shown a peculiar trend [table 2]. The value has shown initially drop in conductivity at 0.2 gm of concentration (sample Pc_2), but later on stepper rise. This is mainly attributed to the increased concentration of conductive material on the surface of the fabric. However, uniform distribution of Nano particles with increased concentration, drop in the value for (sample Pc_2) need further investigation.

Table 2: Calculated conductivity value of Samples

Sample code	$CuSO_4.5H_2O$ (gms)	Electrical Conductivity (ohm meter)
Pp	0	0
Pc_1	0.1	$6.896x10^4$
Pc_2	0.2	$2.66x10^{-5}$
Pc_3	0.3	$4.44x10^4$
Pc_4	0.4	$14.28x10^4$

IX. CONCLUSION

Polypropylene nonwoven fabric was treated with different concentration Nano solution to realize desired conductivity for the application of textile electrode. The presence of Nano particles in the structure has been well identified by microscopical examination as well as FTIR spectroscopy. The electrical conductivity of the sample has shown stepper rise with increased conductive Nano deposition except sample Pc_2.

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