CONDUCTIVE POLYMER COATED TEXTILES FOR BIOSIGNAL MONITORING

N.MUTHUKUMAR¹ & G.THILAGAVATHI²

¹,²Department of Fashion Technology, PSG College of Technology, Coimbatore-641004, India.

ABSTRACT

In the last few years, the smart textile area has become increasingly widespread, leading to developments in new wearable sensing systems. As conventional sensor techniques often cause problems for long term patient monitoring (e.g. skin irritation, hampering wires), elegant solutions are explored to integrate sensors in clothing. By using the textile material itself as a sensor, the integration is increased resulting in even more patient friendliness. Truly wearable instrumented garments capable of recording behavioral and vital signals are crucial for several fields of application. This paper describes the applications of conductive polymer coated textiles particularly polypyrrole in wearable medical monitoring systems.

KEY WORDS: conductive polymers, electrode, polypyrrole, polyurethane foam, smart textile

INTRODUCTION

Wearable computers play a more and more important role in daily life. In the medical field, personal assistants record all the time the physical data of the wearer. Projects to detect and supervise the physical state in real time are running. Personal assistants guide a worker during the operation and maintenance of machines or building cars protect fire fighters from dangerous situations or help people with back problems. Such devices rely on sensors distributed on the human body. Integrating such sensors directly into clothing has several advantages. Clothing is worn almost anytime and an ideal substrate for mounting sensors. They are just at the right place on the body once dressed and the user doesn’t need to care about positioning them. To achieve best integration, textile solutions are favorable. Textile solutions can be made comfortable and unobtrusive for the wearer (Kannian et al., 2011).

One interesting area of research based on conducting polymer has been the development of smart textiles and wearable electronic devices. Conventional smart fabrics are made by weaving metal wire into fabrics, which combines with small electronic components, sensors (chemical, electrochemical or optical) and circuitry to produce smart (metal-based or MB) wearable garments (Muthukumar et al., 2009). Many of the devices available for this type of
sensing rely upon electronic components attached to the material or are not mobile with the wearer. A more innocuous approach is to generate smart fabrics by directly coating conducting polymers onto a substrate material e.g. LycraTM, hence reducing the use of metal component within the fabrics. The major advantages of using conducting polymer (C-P)-based fabrics are that they retain the natural texture of the material and the fabric can be processed as normal. These materials normally work as strain/ pressure gauge and find applications in wearable medical monitoring systems (e.g. for limb movement) for clinical use. In sports applications, performance statistics of an athlete, such as heart rate and breath volume, can be monitored by noninvasive means using equipment such as cardiocameters and spirometers. Much research focuses on monitoring and correcting the amount and spatial distribution of pressure to reduce the risk of repetitive strain injuries (RSI) and noncontact ligament injuries (Van Langehove, 2007)

PPy-coated textiles are often used in wearable sensing applications (De Rossi et al., 2003). These applications generally use knitted textiles, resulting in a sensor with the ability to respond to stretch with increased conductance (Kannian et al., 2011). However, a garment-integrated knitted sensor relies on the ability of its garment housing to also stretch, requiring the garment to be constructed from extensible textiles. Such a configuration also relies on minimizing the wearing ease present in the garment (the difference between body measurements and garment measurements). In other words, the garment generally must stay very close to the wearer’s body in order for length changes in body segments to cause the garment to stretch (instead of simply shifting over the body surface). In many cases, a skin-tight garment can be socially inappropriate or physically or aesthetically unacceptable for the user.

CONDUCTIVE FABRIC BASED STRAIN SENSORS

Scilingo et al., (2003) shown that fabrics coated with conducting polymers, in particular, polypyrrole, have piezoresistive and thermoresistive properties. They investigated these properties to realize strain sensors, which may have useful applications in the broad area of man–machine interfaces. In particular, these fabrics are easily integrated into truly wearable, instrumented garments capable of recording kinaesthetic maps of human motor functions with no discomfort for the subject. Using these fabrics, enable the measurement of shape, detection of posture, and gesture of the human body. They developed a prototype of a sensorized glove to detect the position and motion of fingers relative to the palm and a sensorized leotard for upper body movement tracking. Figure 1 and 2, respectively, show the mask utilized to produce the glove and the glove with the sensors.
Xiaoyin Cheng et al., (2005) reported that sensitivity and stability are mainly factors to hold back the practical applications of polypyrrole coated fabrics. They fabricated a flexible fabric strain sensor with high sensitivity, good stability and large deformation by depositing a nano-layer (200nm to 300nm) of polypyrrole on the 83% Tactel and 17% lycra (195g/m²) fabric substrate at low temperature. Polypyrrole coated fabrics so prepared exhibits a high strain sensitivity of 160 for a deformation as large as 50%, while its good stability is indicated by a small loss of conductivity after the thermal and humidity aging tests, and supported by the slight change in
conductivity and sensitivity over a storage of eighteen months. The developed flexible strain sensor is expected to be a promising "soft" smart material with good sensing properties in the preparation of smart garment, wearable hardware and biomedical applications.

O.H. KW et al. (2003) investigated changes in conductivity with repeated fabric extension to improve the properties of conductive electrode pad material used for electrotherapy. For this they prepared highly stretchable and conductive fabrics by in situ chemical polymerization of polypyrrole on nylon–spandex stretch fabric. They evaluated performance of prepared stretchable conductive fabric in terms of conductivity changes as a function of tensile strain, repeated extension, and current application time. They showed that the conductivity increased when the degree of extension increased, and leveled off when the fabric was subjected to 60% extension. The number of fiber contacts in nylon–spandex fabric with electrode increased as the applied extension increased. However, the conductivity of the composite decreased under excessive extension over 60% since the intrinsic elasticity of fabric became gradually reduced. Generally, the fabric conductivity decreased as the number of extension cycles increased. However, the fabric conductivity was well maintained after repeated extension over 30 cycles at 40% extension. In addition, they found that the current flow through the prepared electrode pad during the electrotherapy treatment is negligible.

CONDUCTIVE FABRIC BASED PRESSURE SENSORS

Brady et al., (2005) developed compressible conducting material by coating polyurethane (PU) foam with inherently conducting polypyrrole (PPy). They showed that there is a linear relationship exists between the conductance and the stress applied over the conductive foam. They also found out the parameters such as sensitivity, dynamic range, repeatability of the conductive foam. They reported that the developed soft pressure foam sensor can be used as a breath monitor.

Dunne et al., (2005) developed pressure-sensitive foam and used in wearable sensing. The developed foam sensor is composed of polypyrrole-coated polyurethane foam, which exhibits a piezo-resistive reaction when exposed to electrical current. The use of this polymer-coated foam is attractive for wearable sensing due to the sensor's retention of desirable mechanical properties similar to those exhibited by textile structures. They developed a sensing garment using the developed foam sensors in several areas on the torso (Figure.3) to measure breathing, shoulder movement, neck movement, and scapula pressure. The foam exhibits a positive linear conductance response to increased pressure. They showed that the polypyrrole coated foam responds in a predictable and measurable manner to breathing, shoulder movement, neck movement, and scapula pressure. The polypyrrole coated foam shows considerable promise as a sensor for medical, wearable, and ubiquitous computing applications. They also stated that the
investigation of the foam's consistency of response, durability over time, and specificity of response is necessary.

![Figure. 3: Sensing garment structure and sensor Layout](image)

In their other study, these authors (2005) investigated that the types of body signals that can be reliably monitored using the foam-based pressure sensors. Specifically, in the garment-integrated wearable configuration the foam sensor has been shown to be capable of accurately responding to absolute stimuli: detecting the occurrence of an event, in a switch-like interface. Further, the sensor is able to provide some indication of the magnitude of that event, but without a great deal of precision. They showed that the sensor is well-suited to interfaces where event detection is the priority, and where more precise information about the event itself is either not necessary or can be provided by other means.

Although this kind of event detection can be achieved by other sensors, the main advantage of this particular sensor is in its physical qualities. The foam structure retains the attractive tactile and mechanical properties of foam, which are similar to those of many textiles. Thus, it is easily integrated into standard garments without requiring any decrease in comfort on the part of the user, and without creating any significant visual indication of the presence of a sensor. These benefits allow the interface to be as subtle and unobtrusive as possible. The sensor is also inexpensive, durable, and washable: all attractive factors for wearable technology. Further, the wearability scenarios to which the sensor is best suited (garment integration, minimally invasive sensing) are those in which many applications require a lower level of precision from body sensing (Muthukumar and Thilagavthi, 2011).
CONDUCTIVE FABRIC BASED ELECTRODES

Today disposable Ag/AgCl electrodes are most commonly used in ECG and EEG measurements. A weak point of these electrodes is a short operating time, only few days. Furthermore, these electrodes are not reusable. Because the few-polarizable Ag/AgCl electrode is usually used as the conventional wet electrode, conduction gel has to be applied to moisturize the skin outer layer and change it to a highly ion-conductive layer. These procedures usually make trouble to users easily; in particular, conduction gels will inevitably leave its residues on the skin. Conduction gel may also leak out the electrodes to cause short circuit between two electrodes in the close proximity, when too much gel is applied. Moreover, these aforementioned preparation procedures are time consuming, uncomfortable, and even painful for participants, since the skin preparation usually involves the abrasion of the outer skin layer. Repeated skin preparations and gel applications may also cause allergic reactions or infections. The signal quality may degrade over an extensive time as the skin regenerates and/or the conduction gel dries.

Textile electrodes are electrodes type, which are made from fabric. Normally, textile materials are insulators, but in the textile electrodes conductive yarn is attached to the fabric during their manufacturing process. These electrodes do not need gel to achieve connection to the skin. The textile electrodes can be made by weaving, knitting or embroidering conductive yarn to the structure

I-Jan Wang et al., (2010) fabricated a wearable mobile electrocardiogram monitoring system for long-term ECG monitoring shown in Figure. 4. In their work, the wearable ECG acquisition device integrated with dry foam electrodes and the ECG acquisition module was designed for long-term ECG monitoring in daily life. Moreover, the ECG acquisition module is small-volume, wireless and low-power consumption (long-term ECG monitoring over 33 hours). By using the wearable ECG acquisition device, patients can monitor their ECG states more comfortably in daily life. And based on SMS communication technology, patients can monitor their ECG anywhere in the globe if they are under the coverage of GSM cellular network. They also tested the patients of atrial fibrillation in China Medical University Hospital, Taiwan using the developed wearable mobile electrocardiogram monitoring system. For 25 AF patients, the sensitivity and positive predictive value of the developed system were 94.56 % and 99.22 % respectively. They showed that the developed wearable mobile electrocardiogram monitoring system (WMEMS) can effectively monitor ECG, and really provides a good system prototype for telemedicine applications.
Chin-Teng Lin et al., (2011) developed and experimentally validated a novel dry foam–based textile electrode for long-term EEG measurement. They fabricated the foam electrode, using electrically conductive polymer foam covered by a conductive fabric. The design of the dry foam electrode is shown in Figure 5. Different from the conventional electrode, the dry foam electrode exhibits both polarization and conductivity due to the use of conductive fabric, which provides partly polarizable electric characteristic, and can be used to measure biopotentials without skin preparation and conduction gel. In addition, the foam substrate of the dry electrode allows a high geometric conformity between the electrode and irregular scalp surface to maintain low skin–electrode interface impedance, even under motion.

The foam electrode was covered by the conductive fabric on all surfaces and then paste on Cu layer.
CONCLUSIONS

This paper reviewed the state-of-the-art in research and development of conductive polymer coated fabric sensors for health monitoring. The described conductive polymer coated sensors integrated with clothing allow measuring the bio signals of the human body and can be placed on different types of apparel (a shirt or a blouse). Their advantage is that they do not interfere with the human body and their textile form does not cause discomfort of use. Moreover, it has been pointed out the use of these conductive polymer coated fabrics as a valid alternative to existing instrumentation applicable in several health care areas.

REFERENCES


