

WEARABLE PHOTONIC BIOELECTRIC MONITORING DEVICE

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ABSTRACT

Wearable devices are used to record several physiological signals, providing unobtrusive and continuous monitoring. The main challenge in these systems is to develop new recording sensors ideally envisioning non-contact solutions. In this work we propose a wearable fiber-optic based sensor which basis of operation relies on the electro-active effect. Two main biopotential sensing components were investigated: a lithium niobate electro-optic modulator and an electro-active hydrogel (Polyacrylamide). Both approaches have shown satisfactory results in terms of sensitivity and frequency response, placing them as eligible sensing components for wearable biopotential recording applications.

INTRODUCTION

The need to provide personalized healthcare systems is driving the development of wearable biopotential sensors. Such non-obtrusive devices can provide the user with a comfortable and easy-to-wear garment, for instance a cap or a t-shirt, and allows people to perform everyday activities requiring minimal training and preparation.

To provide sensors for truly portable and wearable devices, properties such as easy integration and miniaturization, lightweight, flexibility, low power consumption and real time monitoring, are required (Winters and Wang 2003). Therefore, these wearable devices can profit from the use of optical techniques that fulfill the stated requirements. Such optical techniques, since based on optical fibers, can provide easy integration into textiles and other wearable materials. In addition to the integration feature, optical sensors are immune to electromagnetic interference, resistant to harsh environments, and are electrical wire free (Winters and Wang 2003).

In this work we propose the development of fiber-optic based sensors for integration in wearable materials envisioning the bioelectric signals monitoring.

WEARABLE BIOELECTRIC MONITORING DEVICE

The wearable bioelectric monitoring device proposed employs the use of a new generation of fiber-optic-based sensors, aiming for a contactless recording of bioelectric signals. An optical readout method is proposed, which uses optical sensors placed at the fiber tips in order to sense the electric field, i.e. the biopotential. Each fiber routes the signal to the readout device, creating a net of optical fibers to provide access to all the desired recording locations. Figure 1 depicts the topology of the proposed sensor envisioning a specific application for EEG recording using a wearable brain cap.

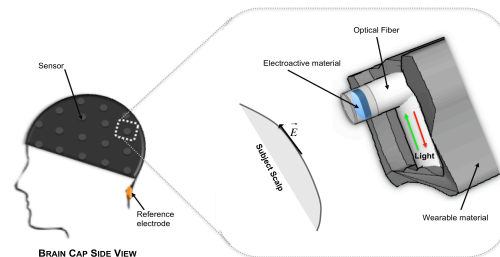


Figure 1: Photonic Sensor for Wearable Bioelectric Sensing Applications

The readout solution is based on the electro-active principle, in order to use electric field to modulate an optical signal. The main functional stages of this sensor are: optical signal generation; control and modulation; and detection. Briefly, the first stage uses a light source to generate an optical signal that will be fed to the modulator. In a second stage, an electroactive material or device will change a specific light property (e.g. polarization, intensity). Regarding the detection stage, a photodetector, which incorporates a transimpedance amplifier, is used. The light property modification observed is proportional to the biopotential itself, being therefore possible to translate this result into a biopotential recording. Many solutions may be envisioned regarding the modulation stage of the optical electrode. In this work, we have studied and developed two main approaches based on electro-optic (EO) modulators and electro-active coating materials.

EXPERIMENTS AND RESULTS

Electro-optic methods

The effect behind the EO acquisition of biopotentials is the EO effect, which refers to changes in the

refractive index of a material and its effect on polarized light, induced by the application of an external electric field (Shun Lien 2009). Of the different existent modulators, we propose the use of an intensity EO Modulator with a LiNbO₃ Mach-Zehnder (MZI) geometry. The use of this type of geometry allows for the conversion of the induced phase shift by the external electric field, into an intensity variation, by interfering two waves of the same frequency but different phase.

We have acquired ECG signals by this EO technique, both with conventional electrodes as well as with in-house fabricated dry PDMS-based electrodes. Figure 2 shows the ECG records obtained for both types of electrodes.

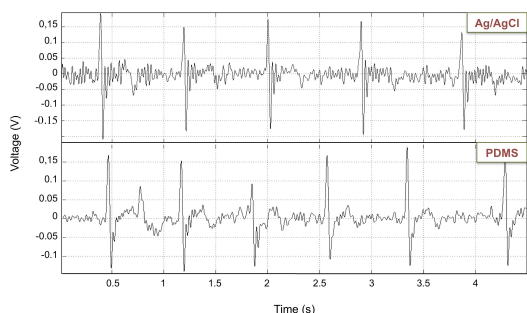


Figure 2: ECG Recordings using an EO Setup for Ag/Ag Electrodes and In-house Fabricated Dry PDMS-based Electrodes

Results have shown a good performance of this technique whether in wet or dry conditions, in terms of sensitivity and noise reduction. A more detailed set of results and its discussion can be found in (Fernandes et al. 2010a).

Electroactive hydrogel-based method

The proposed methodology uses an electro-active hydrogel – Polyacrylamide (PAAM) – which when submitted to an external electric field, undergoes a bending process, altering its mass and volume properties. When an input light passes through the gel, it will experience modifications, not only regarding the refractive index but also the amount of light transmitted to a photodetector. This electro-active hydrogel was tested as a candidate for the sensing component of our sensor by placing it between two copper electrodes inside a beaker, while applying a 1V sinusoidal electric field. Light passing through the gel is collected at a detection module. Figure 3 shows the frequency response of the PAAM hydrogel.

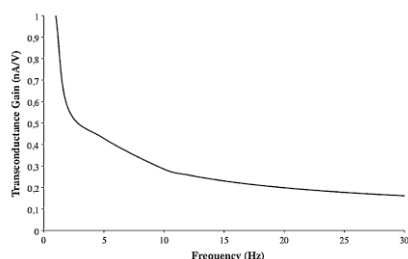


Figure 3. PAAM-hydrogel Frequency Response

The results have shown an adequate sensitivity in the range of μV , as well as a good frequency response, pointing the PAAM hydrogel sensor as an eligible sensing component for wearable biopotential recording applications. A detailed discussion of these results can be found in (Fernandes et al. 2010b).

CONCLUSIONS

A new generation of wearable sensors for biopotential measurements based on optic techniques was described. This fiber-based integration approach, which basis of operation relies on the electro-active principle, results in several advantages regarding the existent methodologies: easy integration and miniturization, lightweight, flexibility, resistant to harsh environments, immune to electromagnetic interferences, among others.

In this work, we have studied and developed two main approaches based on electro-optic (EO) modulators and electro-active coating materials. Both approaches have shown satisfactory results, showing adequate sensitivity and frequency response. However, further work must be done towards achieving contactless recordings of biopotentials and full characterization of both EO and hydrogel-based sensors.

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