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Imperceptible Sensorics for medical monitoring

A stretchable and flexible platform for epidermal electronics

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Society is aging so there is a need for new reliable mobile health monitoring systems. A wireless, stretchable and mobile health monitoring platform has been developed which consists of a wireless stretchable, biocompatible sensor tag placed on the skin and an RFID reader which collects and evaluates data and shows it on a display.

Keywords— medical technologies, epidermal electronics, mobile devices

I. Introduction

The measurement of various physiological parameters of the epidermis has been the object of studies for more than 80 years [1]. A large number of works on solid wafer–based measurement techniques can be found in the literature, for example the use of a glucose watch was proposed [2]. The glucose watch should noninvasively measure the blood sugar level. Most of the described sensors never reached the market because of problems related to the robustness of the electrical contacts to the epidermis, miniaturization issues, and inadequate portability. Attributes like small size, lightweight, and biocompatibility are very hard to achieve in a single device. The most recent studies have focused on stretchable membranes, which may fulfill all the above-mentioned requirements (Fig. 1).

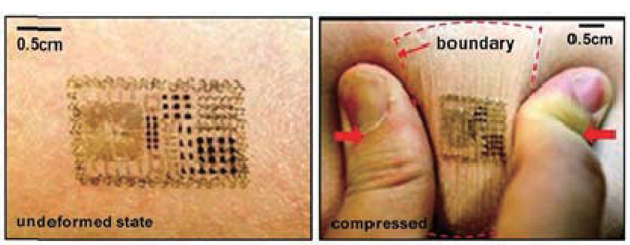

Fig. 1. Electronic epidermal system [3]

The field of electronic systems on flexible substrates has been emerging in recent years with the development of systems on foil for different applications such as circuits, displays and sensors. The latter includes the development of sensors for temperature [4] and pressure [5]. Flexible sensing systems for on-body applications range from pressure, temperature, humidity, strain, ECG sensors [3] to body movement. In 2015 even a flexible sensor which can noninvasively detect skin cancer by measuring mechanical moduli in soft biomaterials was presented, which was previously not possibly even with highly sophisticated medical devices [6]. Wearable flexible and stretchable devices are not only more comfortable, but in many cases, due to their size and mechanical properties, they can be located in places where measurements were simply not possible previously. Data collection can be performed in real time, which is significant in medical diagnostics.

Our approach aims to develop a mobile sensor platform consisting of a wireless stretchable tag placed on the skin or a wound and can communicate wirelessly with a mobile device. The system should be reliable and user friendly.

II. METHOD

We have designed, produced and tested a wireless, stretchable and flexible health monitoring tag featuring connectivity with mobile applications. The tag, which has been produced by lithography and micro structuring techniques, contains medical sensors and an RFID antenna. The platform has been successfully tested with a commercial temperature sensor and an impedance-based sensor for human fibroblasts. Below we describe each component of the development platform in detail.

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A. Stretchable wireless tag

We have built a stretchable wireless tag made up of a thin Cu layer and commercial electronic Surface Mounted Devices (SMD). The electronic circuit is encapsulated within two layers of stretchable, flexible and transparent polymers. The tag is lightweight, biocompatible and has a size of 25 mm x 50 mm x 5 mm. Furthermore, it adheres itself to the skin using van der Waals forces, so it can easily be located on the epidermis. The tag can accommodate various sensors and sense bio-signals from the human body.

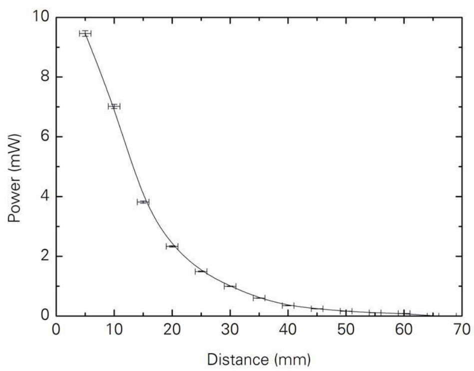

Fig. 2. Power transfer between the tag and the reader

The device is passive and works only when the RFID reader provides electrical power in close proximity. The maximal distance for power transmission is 50 mm (Fig. 2). We tested the device successfully with commercial rigid sensors as well as flexible temperature sensors developed in house. We are also working on more complex applications such as wound monitoring. As a proof of concept, in order to understand the biological implications during wound healing, we focused on human fibroblast cell lines and studied the influence of external parameters on their growth behavior. We then performed *in vitro* experiments on cell culture samples, measuring changes in their frequency-dependent impedance with variations in cell layer density (Fig. 3). For the *in vitro* studies related to human wound healing, the well-known, stable and widely available human cell line Hs27 (ATCC® CRL-1634TM) was chosen. Hs27 is one of a series of human foreskin fibroblast lines [7], [8]. The material was obtained from a normal newborn black male. The culturing took place an incubator at 37 °C with 5 % CO_2.

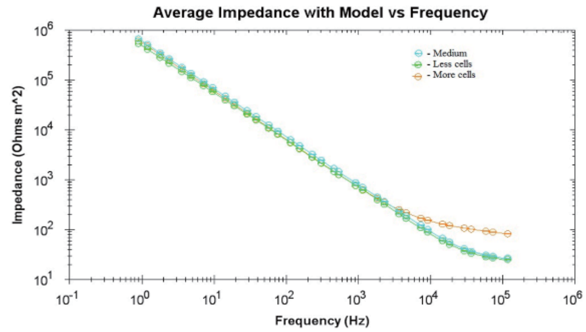

Fig. 3. The dependence between the amount of the cells and the impedance of the gold electrode – qualitative data

Cells were cultured in 16 well E-Plates which are part of the xCelligence® impedance measurements system (ACEA Biosciences). 80 % of the bottom area of the wells in the E-Plates was covered with gold electrodes, which enabled the cell impedance measurements. The measurements were taken by an impedance measurement station (INPHASE UG). As can be seen in Fig. 3, the change of impedance value can be observed by frequencies higher than 10 kHz. The bottom line shows values collected for medium solution. The middle line responds to cell density after 8 h of culturing and the top line corresponds to the state after 12 h culturing. In the next step, fibroblasts were seeded in standard culturing flasks. The confluent layer of cells was injured by creating a ‘scratch’ (a straight line) with a glass pipet tip. Subsequently, cells migrated and ‘healed’ the scratch-wound, which can be seen in Fig. 4.

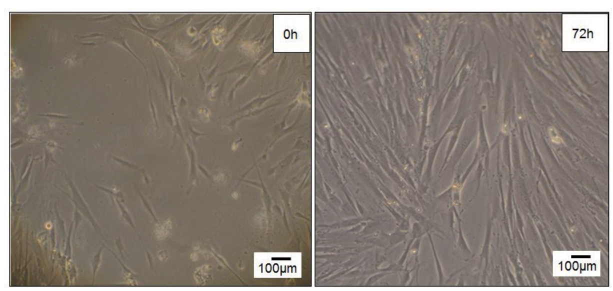

Fig. 4. Scratched surface (left), scratched surface after 3 days (right)

This process was investigated using a standard optical microscope and the wound healing process is shown in very simple terms, in vitro. It is visible that the amount of cells increases dramatically in the place where there was previously a scratch. This change can be measured using impedance spectroscopy. Such scratch assays are used to study the migration of cells [7], [8].

B. RFID reader for PC

Regarding the RFID reader, we designed and built on a printed circuit board (FR4, 1.55 mm) a wireless receiver for PCs working at a frequency of 13.56 MHz (Fig. 5) and powered by a cable from a computer.

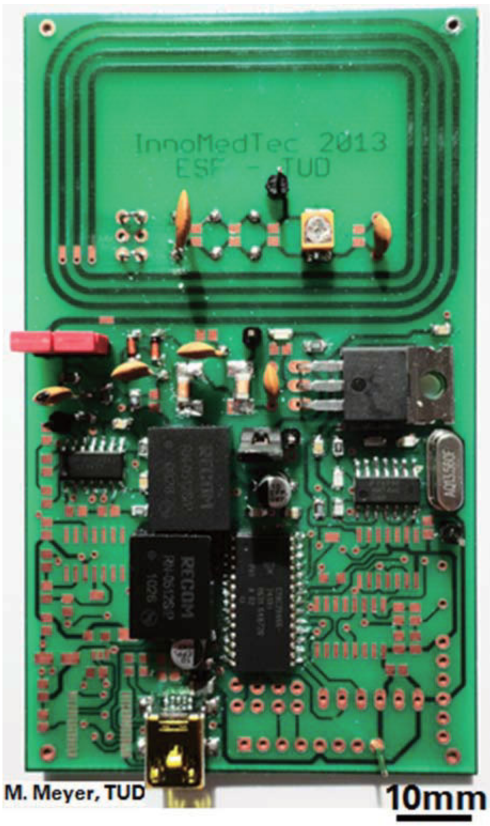

Fig. 5. RFID reader for PC

The RFID reader can wirelessly power the tag containing the medical sensors and collect data through the wireless communication channel. The maximal sensing distance between the antenna (size 30 mm x 50 mm) on the sensor tag and the receiver antenna is 30 mm. The reader collects the data, which is amplified, filtered, and, most importantly, processed to extract features of interest.

C. Application

We developed a basic PC application that can recast the outputs of the signal processor in a patient-friendly way and show them on the display of the computer, as shown in Fig. 6.

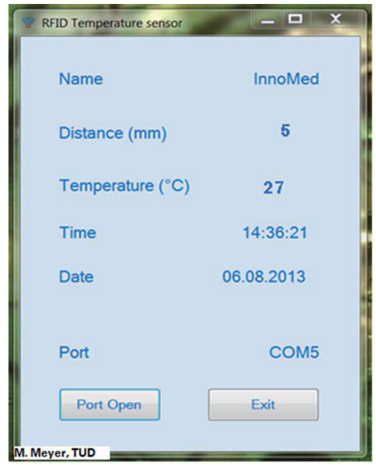

Fig. 6. PC program for the sensor platform

The application makes it possible to evaluate and save data and, if necessary, wirelessly transfer a report to a physician, who can answer with a recommendation for further treatment. The user can also modify the layout in order to adjust it to his needs, as well as access archived measurements and generate statistics at any time. Strong emphasis was put on simplicity, so that even users with little experience of electronic devices should not have problems using the application.

III. Summary and Outlook

In summary, we have developed and built a first implementation of a wireless stretchable health monitoring sensor platform, consisting of an RFID tag with medical sensor, an RFID reader for a PC, and a PC-based application for data collection and further processing. The results described above are the basis for further development of a mobile medical sensor platform. In the next steps, more medical sensors will be connected and tested. Finally, the system should be put on the market as a product for physicians, patients, as well as everyday users who would like to noninvasively monitor their health status. Moreover, the idea has unlimited possibilities for further development and implementations not only in the health care sector, but also in industry and in everyday use.

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