Skin Variations Impact on Non-Invasive Measurement of Blood Glucose with Interdigital Electrodes

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Abstract

Diabetes is a major health issue which currently affects more than 300 million persons worldwide [1]. One key activity for the proper management of the disease is the regular monitoring of blood glucose levels in order to establish the insulin dosage [2]. Currently most blood glucose monitors require a blood sample for each test, resulting in significant discomfort to the patient, particularly children and the elderly [3]. The non-invasive measurement of blood glucose using interdigital electrodes is a potential less painful alternative [3]. Previous work has been conducted to establish the viability of the measurement method using simulation models and testing. However, little work has been conducted on examining the effect of the measurement-site skin-topology (skin roughness, scarring, etc.) on the sensor performance [4-6]. This work examines the behaviour of a simple interdigital sensor in response to skin-topology distortions and differences in skin undulation during use. The study then considers a flexible sensor structure which is better able to contour to skin variation.

Based on the interdigital sensor structure complexity it was necessary to construct a 3D model of the sensor. The AC/DC Module of the COMSOL Multiphysics® software was used to simulate the capacitance of the interdigital sensor structure. Electric Currents physics was used in a Frequency Domain study. For the examination of skin distortion three (3) scenarios were considered: sensor directly against the skin, electrodes embedded within the skin, and sensor embedded 0.4mm within the skin. For the consideration of skin undulation, the scenario of skin surface undulation due to the presence of a blood vessel was contrasted with the ideal scenario of the sensor directly against a perfectly flat skin surface. Finally, a flexible sensor structure which contours to the deformed skin surface was considered. In all cases, the model capacitance was calculated over a frequency range of 10kHz - 1MHz using 10kHz steps.
For all testing scenarios the measured capacitance was seen to decrease as the signal frequency increased. For the skin distortion scenarios, the measured capacitance was seen to increase the further that the sensor structure was positioned into the skin's surface. For the skin undulation scenarios, the measured capacitance was seen to be significantly smaller for the case of the rigid sensor on the deformed skin's surface compared to the ideal case. However, the flexible sensor was seen to closely match the capacitance values of the ideal case. This work demonstrates that skin distortion due to, for e.g. pressing the sensor into the skin's surface, results in a significant variation in sensor reading compared to the ideal scenario. For the instances of skin-topology undulation, significant variations in readings were obtained when the sensor was displaced from

the surface. Finally, a flexible sensor was shown to provide performance comparable to the ideal measurement conditions which can potentially allow for the compensation of undulations in the skin-topology.

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Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4