Thin Film Interdigitated Electrode Arrays Applicable for Non-Invasive Monitoring of Human Skin.

[1]Ivanic, R., [2]Weis, M. , [3]Danilla, T., [1]Tvarozek, V.

[1]Department of Microelectronics, Slovak University of Technology, Ilkovicova 3, 812 19 Bratislava, tel: +421-7-60291 731, fax:+421-7-654 23 480, e-mail: ivanic@elf.stuba.sk
[2]Institute of Medical Physics and Biophysics, Comenius University, Bratislava
[3]Department of Dermatology, University Hospital, Bratislava

The general principle of the human skin electrical properties measurements is a special configuration of the electrode system with electric field lines of vector intensity $\bar{E}$ across (transversely) planar structures of skin. An application of the electrode systems for electric parameters measurement in dermatology has to take in consideration the relation between thickness of the skin and the distance of electrode. Electrical properties of the human skin measuring system have been simulated using program PSpice and QuickField. With aspect of theoretical and simulated analysis non symmetric IDA electrode arrays system were designed and fabricated.

1. Introduction

Microelectrodes are playing very important role in advanced electrochemical microsensors. Their use offers advantages such as diffusion-controlled currents, low charging currents, and reduced solution resistance effects. Interdigitated array (IDA) electrodes with geometry in the range of micrometers are especially attractive since they possess the advantages of new measurement possibilities [1]. Planar interdigitated electrode arrays are a commonly used electrode configuration for conductometric sensing applications [2].

Measurements of the electrical properties of human skin (such as conductivity, resistance, impedance, e.g.) have a lot of modification. The general principle of these methods is a special configuration of the electrode system with electric field lines of vector intensity $\bar{E}$ across (transversely) planar structures of skin. The electric barrier resistance of the skin R_B (Fig. 1a) characterizes this configuration.

The analytical solution of the potential of the electrostatic field follows from solution of the Laplace differential equation. Electrostatic field of IDA electrode arrays across human skin structure has been simulated by program QuickField. Electrical properties of measured system have been simulated using program PSpice.

2. Topology of conductance microelectrode sensor system

An application of the electrode systems for measurement electric parameters in dermatology has to take in consideration the relation between thickness of the skin and the distance of electrodes. If the distance d of coupled electrodes is greater than the skin thickness h, the vector intensity lines of the electric field $\bar{E}$ are enclosed across the planar structures of the skin. This effect is due to high electric conductivity of subcutaneous tissue. In coherence with electrostatic field this tissue is equipotential area and operates as an independent electrode. This configuration is characterized as the electric barrier resistance of the skin R_B (Fig. 1a).

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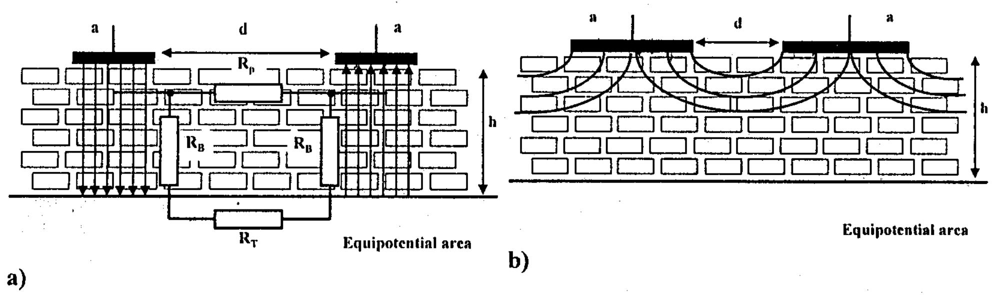

Fig.1 The vector intensity lines of the electric field Ē in human skin: a) $d \geq a; d > h$ b) $d<h$

If the distance of the electrode pairs is lower then than the thickness of the skin, then the lines of electric field are enclosed of circuit longitudinal to laminar structures stratum corneum SC (Fig. 1b). The planar electrode structures with electrode structures with electrode elements are on the plane interface with a biological half-surrounding ε_{rBIO} and the half-space consisted of the dielectric substrate ε_{rSUB}. The analytical solution of the potential of the electrostatic field follows from solution of the Laplace differential equation.

The results of analytical analysis have shown, that in a non-symmetric coplanar electrode electric field is more enclosed in laminar structures. This system consists of electrodes periodical structure with diferent areas (Fig. 2). This effect appear when the ratio between electrodes is $a/b \geq 3$. The density of the vector intensity lines of the electric field Ē across the planar structures of the skin in non-symmetric structure is 30 % higher compare to symmetric structure[3].

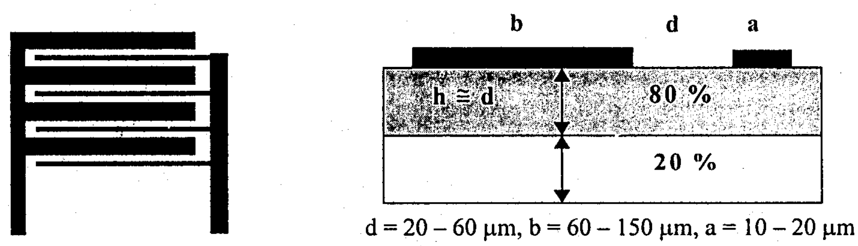

Fig. 2 The penetration depth of the electric field Ē at non-symmetric electrodes array.

Electrode field is implement into human organism by electrode system situated at the skin surface. Measurements and behavior of this electrode system defines electrical field (intensity E, potential V) in human organism. The present state of planar and thin film technologies developed for microelectronics render possible the miniaturization of known principles and their transformation from 3D to 2D planar systems. The transformation of present 3D sensors technology to planar technology and process of the miniaturization often lead to new qualities.

3. Modulation and simulations

Beside its important function as an efficient permeability barrier for water and other compounds it plays an important role to keep human skin soft and smooth. The water content within the SC is an important variable for its plasticity and elastic properties [4]. With change of water concentration coming to change of relative permitivity and conductivity of SC.

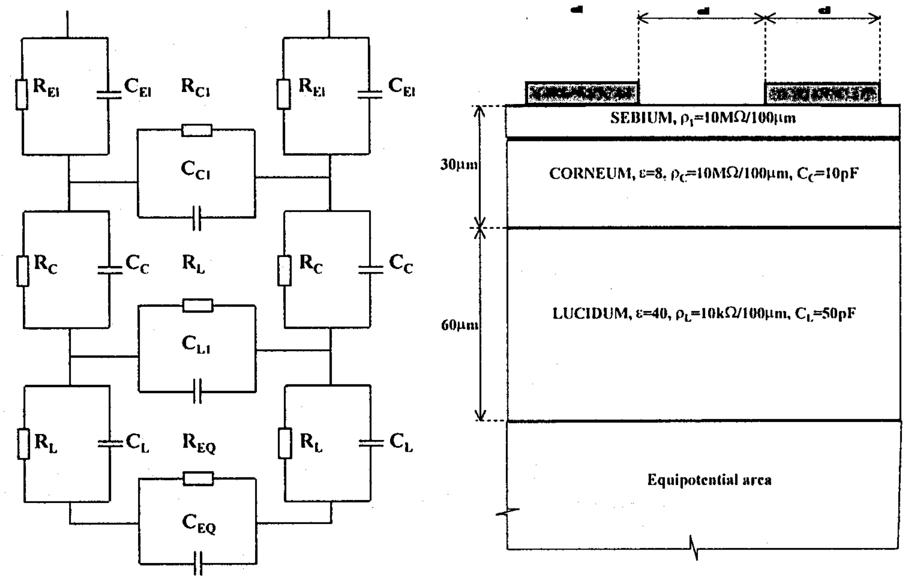

Fig. 3 Equivalent circuit of human skin measurement system

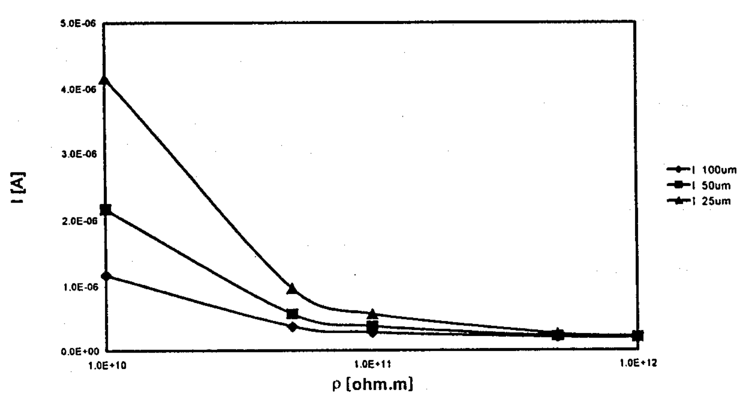

Fig 4 Simulated data of microelectrode measurement system

In Fig. 3 is showed equivalent circuit of human skin measuring system. R_E and C_E characterized the electrical parameters of electrode system, R_C and C_C of SC, R_L and C_L of lucidum, R_{EQ} and C_{EQ} of equipotential area. The electrical parameters have been calculated from parameters published in [2,3,4]. Measurements and comparation of system sensitivity (dI/dρ) have been simulated for symmetric electrodes with dimensions a,b,d=100μm, 50μm and for non-symmetric electrode with dimensions a=15μm, b=25μm, d=50μm. The change of physiological condition and composition of SC have been simulated by change of R_E and C_E values.

With decreasing of distance between IDA fingers are increasing the sensitivity of simulated system (Fig. 4). This is due to decreasing of R_C values. If the distance between IDA fingers is smaller than thickness of upper laminar structures the role of the parameter R_{CI} rise up because it is starting be smaller then R_C values. Simulation of electrical field by QuickField showed that vector of electrical intensity of non-symmetric IDA system is more enclosed in upper laminar structures with comparison to symmetric IDA systems. This is cause of next increasing of measurement system sensitivity.

4. Conclusion

Experimental results showed that measurement sensitivity of the characterization of human skin laminar structures with thin film IDA electrode arrays increases in range 10^2 to compare with planar bulk electrodes. The aim of this work has been find suitable arrangement and proportions of non-symmetric IDA electrodes applicable for bio-electrical measurement of human skin. With aspect of theoretical analysis, such as simulation of electrical properties (Fig 4) of human skin and simulation of electrostatic field of IDA electrode arrays, non symmetric IDA electrode arrays system were designed and fabricated (a=15μm, b=25μm, d=50μm).

Acknowledgement

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