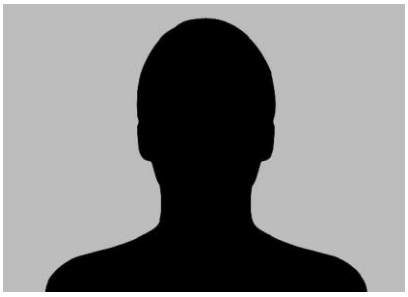
Zurich University
of Applied Sciences

School of
Engineering

ICP Institute of
Computational Physics

Simulating the electrical properties of the human skin for the development of hydration sensors



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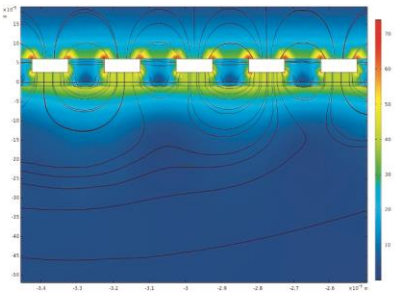
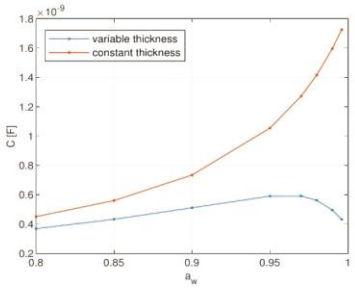
A computational model describing the dielectric properties of human skin helps designing, investigating, and optimizing electrodes for dielectric spectroscopy used in skin hydration monitoring. Human skin is composed of several layers with distinct dielectric properties. The hydration state of skin is an important parameter not only affecting the dielectric properties, but also the constitution. The skin model is set up as a multilayer system, each layer resembling its dispersive dielectric behavior with a Cole-Cole model. Focusing on the stratum corneum layer, a hydration model is additionally employed, which simulates the stratum corneum swelling and varies the dielectric parameters under hydration influence. With different fringing-field sensors on top of the multilayer system, the model is numerically evaluated using the finite-element method. Firstly, by means of the stratum corneum hydration model, the range of water concentration was investigated. At normal conditions, i.e. no skin disease, no sweating, no wounds, the water concentration resulted to be higher than 0.585 g/cm^3, or expressed in water activity 0.9745. Secondly, the influence of the hydration dependent stratum corneum thickness on the dielectric spectroscopy was investigated. It was found that the stratum corneum thickness cannot be neglected. In high water concentration range the swelling reduces the capacity, where the capacity would increase, if neglected. Finally, a sensitivity analysis was performed with three different fringing-field electrode types with various geometries. The sensitivity was calculated from the capacity of various hydration levels in relation to the capacity at fully hydrated skin. The analysis confirmed that the electrode sensitivity is influenced by its geometry and dimensions. However, the sensitivity of the impedance electrodes is stronger affected by dimension change than the capacitance electrode.



Interdigitated capacitance electrode on top of the skin model, with current density as color gradient in (A/m^2) and electric field as stream lines (V/m).



Comparison of the capacity measurement of variable and constant stratum corneum thickness at various hydration levels. Varying the thickness has a significant impact on the measurement, especially in the hydration range above a water activity 0.95.