Towards Multiscale Models for Bioimpedance of Human Skin with COMSOL Multiphysics

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Abstract

Mechanistic mathematical modeling for electrical impedance spectroscopy (EIS) of human skin involves not only the equation of change for the alternating current from and to the electrodes of the EIS probe but also the spatial resolution of the various skin layers and their material properties. The latter requires careful consideration of the inherent complexity of the epidermis, dermis and subcutis.

To develop a complete multiscale mathematical framework that accounts for the physical phenomena of EIS of human skin - both invasive and non-invasive - we use experimentally measured EIS data for the volar forearm to calibrate and validate a first model comprising a complex-valued elliptic partial differential equation for the alternating current for three skin layers: stratum corneum (outermost layer of epidermis), viable skin (living epidermis and dermis) and adipose tissue (subcutis). The calibration is carried out by linking Matlab with COMSOL Multiphysics after a mesh independence study.

With the model, we can study probe design that is both invasive and non-invasive for skin with the fitted material properties and for skin that has anomalies in one or more of the layers. In order to further increase the resolution of the skin layers, we aim to resolve down to the cell level in the three aforementioned skin layers. An additional benefit of doing so should be the derivation of volume average material properties that can be used in efficient, reduced models. We will demonstrate one reduced model that only requires the viable-skin layer with modified boundary conditions in COMSOL Multiphysics.

Figures used in the abstract

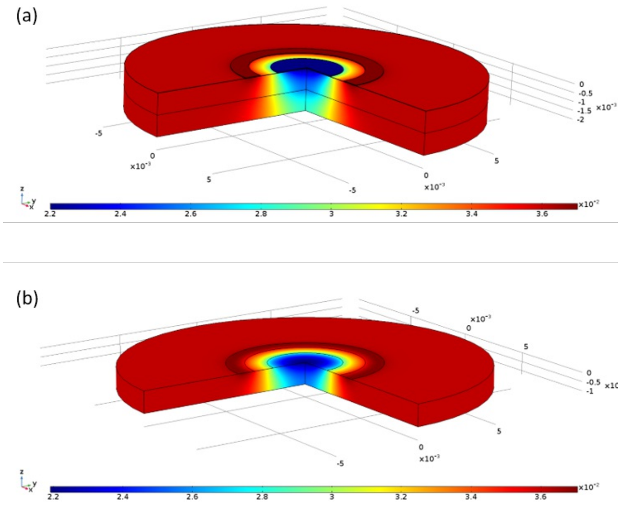

Figure 1: Potential distribution in the electrodes of a four-electrode probe and adjacent skin layers for (a) the complete model and (b) the reduced counterpart at 1 MHz.