Universität Rostock

Traditio et Innovatio

Universität Rostock
welisa
DFG-Graduiertenkolleg 1505/2

DFG

Analysis and Simulation of Electrical Interaction of Implants with Bio-Systems

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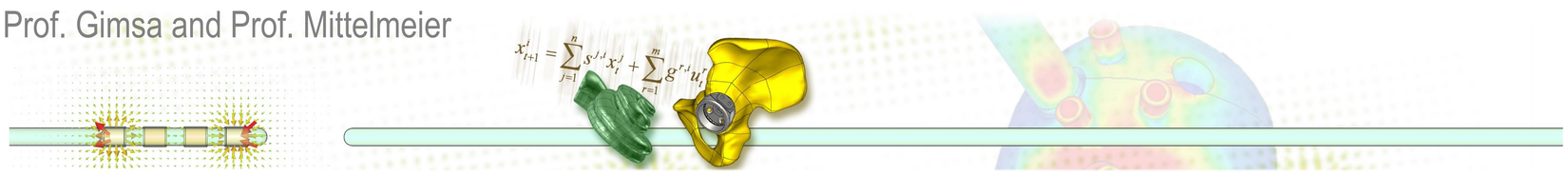
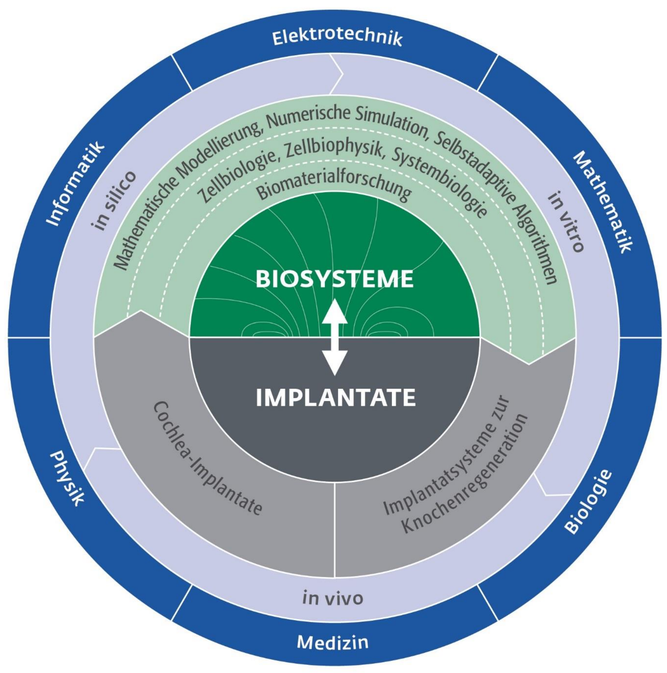


Motivation and Aim

Despite numerous successes with implanted technical systems to support body functions that have been restricted by illness, accident or age, an extended research is needed with the objectives of improved function, greater compatibility and longer durability of implants. A substantial part of the emerging questions is directly connected to the necessity of a profound understanding of the processes at the interface between the implant and surrounding tissue, which in turn requires a detailed knowledge of the electrochemical processes taking place there - if applicable, influenced by externally applied electromagnetic fields.

The precise model description of the processes at the interface between the implant and surrounding tissue from both biological and medical as well as from physical-electrotechnical and biophysical-electrochemical point of view is the central research goal. Within the RTG *welisa* 15 PhD Students are working in parallel on these processes. In the first funding period 2008-2013 experimental analyses of the adhesion and proliferation of osteoblasts, biophysical experiments on electrical coupling of nerve cell networks with sensor chips, electric field calculations and thermodynamic simulations on different size scales have been carried out. To describe the processes, innovative automated statistical methods and techniques from systems biology have been developed. The outcome has direct relevance to the analysis of the electrical interactions between implants and the biological system and thus for the optimization of deep brain stimulation, of cochlear implants and of electrostimulative implant systems for bone regeneration for future clinical application. These findings obtained in the first period will be extended. New for the current period 2013-2017 is to investigate the influence of electromagnetic fields on bacteria and human cells.

Networking within *welisa*



Cochlea Implants and Deep Brain Stimulation

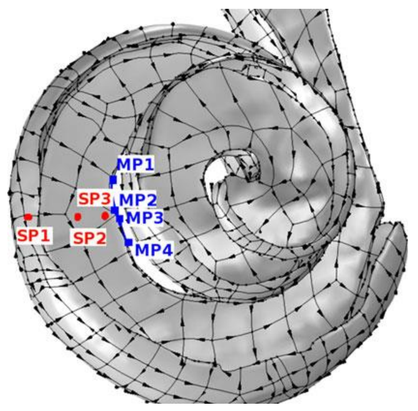


Figure 1: Mathematical model of the cochlea with three stimulation points (SP1–3) corresponding to the lateral (SP1), intermedial (SP2), and medial (SP3) position and four measurement positions (MP1–MP4).

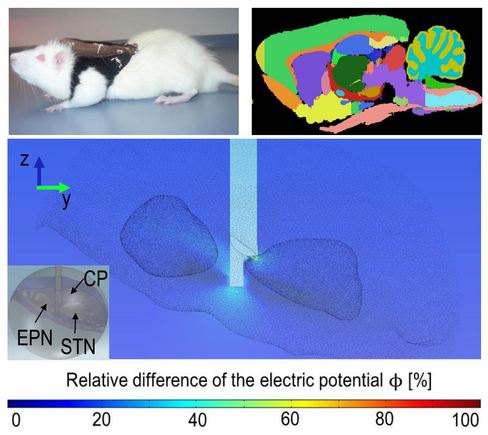


Figure 2: DBS between an anistropic and an isotropic model. Simulating Deep Brain Stimulation (DBS) in an anatomically realistic model based on the Hemiparkinsonian rat model (top left) [1,2] using a segmented Waxholm Space Atlas of the rat brain (top right) [3] to estimate the relative difference* of the stimulation field distribution in the target region for DBS: subthalamic nucleus (STN), entopeduncular nucleus (EPN) and corticofugal pathway (CP).
*relative difference $= |\phi_{iso} - \phi_{aniso}|/\max(\phi_{iso}, \phi_{aniso})$

Experimental Systems for Studying the Interactions between the Electrical Stimulation, Surface Roughness and Cells

While many experiments where osteoblasts are laid on arrays of micro-pillars have been done, the bio-chemo-mechanical model [4] is potentially applicable to our simulation of actin patterns.

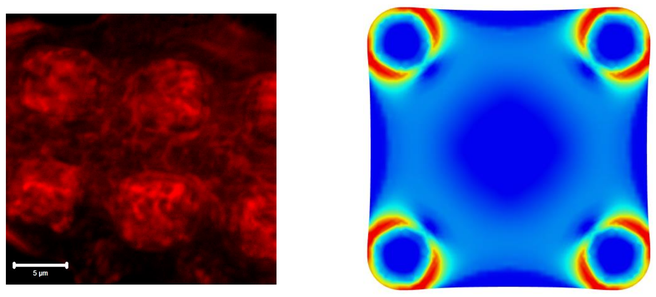


Figure 3: Experiments on osteoblasts utilizing the micro-pillar method conducted at the Department of Cell Biology (left) and FEM simulation of steady-state actin distribution (right) for cell on array of 2×2 pillars conducted at the Department of Electrical Engineering.

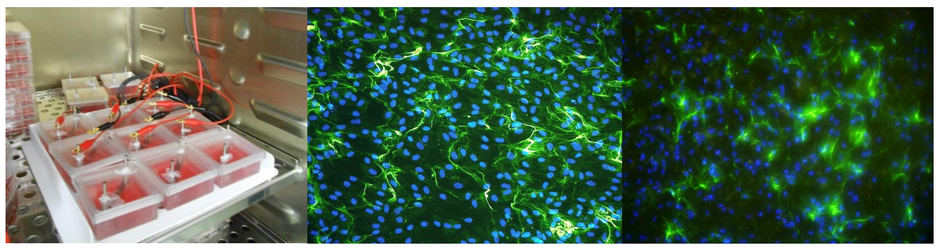


Figure 4: In vitro system for stimulation of osteoblast cells with AC voltage (left). Cells are seeded on top of Ti6Al4V electrodes and coverslips on chamber bottom to determine influence of electric stimulation on growth and differentiation of osteoblasts. Pictures above show collagen type I expression (green) on coverslip (middle) and electrodes (right) after three days of electric stimulation. Cell nuclei are stained with DAPI (blue). Experiments are conducted at the Department of Orthopedics.

References

[1] Badstübner et al., Electrical Impedance Properties of Deep Brain Stimulation during Long-Term In-Vivo Stimulation in the Parkinson Model of the Rat. Biomedical Engineering Systems and Technologies 2013, 357, 287-297.
[2] K Nowak et al., "Optimizing a Rodent Model of Parkinson's Disease for Exploring the Effects and Mechanisms of Deep Brain Stimulation," Parkinson's Disease, vol. 2011, Article ID 414682, 19 pages, 2011.
[3] Papp et al., Waxholm Space atlas of the Sprague Dawley rat brain. NeuroImage 2014, 97, 374–386
[4] McGarry JP, Fu J, Yang MT, Chen CS, McMeeking RM, Evans AG, Deshpande VS: Simulation of the contractile response of cells on an array of micro-posts, *Phil. Trans. R. Soc. A* 367, 2009.

Acknowledgements

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