Universität Rostock

Traditio et Innovatio

Elaine
electrically active implants
SFB 1270

B03 Energy-autonomous platform for electrical stimulation implants

Motivation and Objectives

- Batteries typically supply power to medical implants nowadays
- Battery lifetime requires replacement every 5–8 / 3–5 years for pacemakers / implantable cardioverter-defibrillators, resp.
- Surgical replacement is expensive and bears critical health risks
- Multimodal energy sources and harvesting mechanical or thermal ambient energy could improve implant's lifetime up to energy autonomy
- Patient-specific configuration, sensory information, and real-time feedback control of electrically stimulating implants offer new insights in effect mechanism and pave the way for improved therapies

Typical power demands of human implants (excluding electronics)

	Voltage [V]	Impedance [Ω]	Peak Power [µW]	Duty-Cycle (On:Off)	Average Power [µW]
Bone	0.5	6000	41.67	0.2500	10.42
Cartilage	0.5	6000	41.67	0.2500	10.42
DBS*-Parkinson	2.5	1000	6250	0.0078	48.68
DBS*-Dystonia	4.0	500	32000	0.0078	246.2

*Deep Brain Stimulation (DBS)

Preliminary Work

Interaction of medical devices
- Service oriented interconnection of devices in operational rooms (OR.NET)
- Co-authorship of the IEEE 11073 SDC standard family

Electronic components for the artificial liver MARS
- Commercially available extracorporeal liver dialysis system
- Reliable self-monitoring techniques to fulfill medical regulations

Low-power and high reliability design techniques
- System Management & Monitoring

Fig.: Liver dialysis system MARS

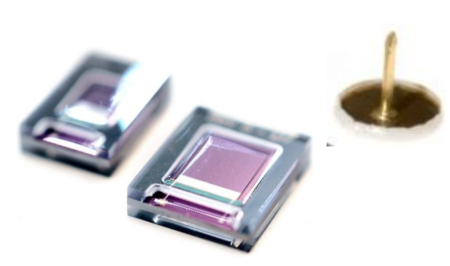


Fig.: Wafer-scale hermetic encapsulation

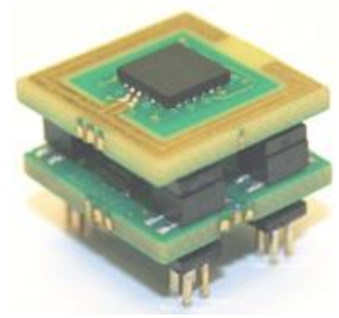


Fig.: energy-autonomous wireless system

Energy harvesting
- Micromechanical silicon-based resonators with piezoelectric energy conversion
- Energy autonomous operation of wireless sensor systems

Advanced modelling techniques for system-level simulation
- Co-simulation of device and analogue/digital circuit models enabled through novel order reduction techniques for multiphysical finite-element models
- Parameter identifications and new optimization techniques through mathematical model order reduction

Methods and Work Programme

Software Defined Implant Platform
- Concept, model, and prototypical implementation of a modular highly integrated **ultra-low power CMOS microelectronic system** suitable for each of the representative types of implants considered in this Collaborative Research Centre.
- Able to handle **three sources of energy** (battery, wireless energy transmission, several types of **energy harvesting**) as well as bidirectional wireless communication in an extremely energy-efficient manner.
- Lifetime of primary energy storage shall be increased and could potentially become unlimited.
- Software based configuration and monitoring of the implant's operational parameters as well as the patient's biological status.

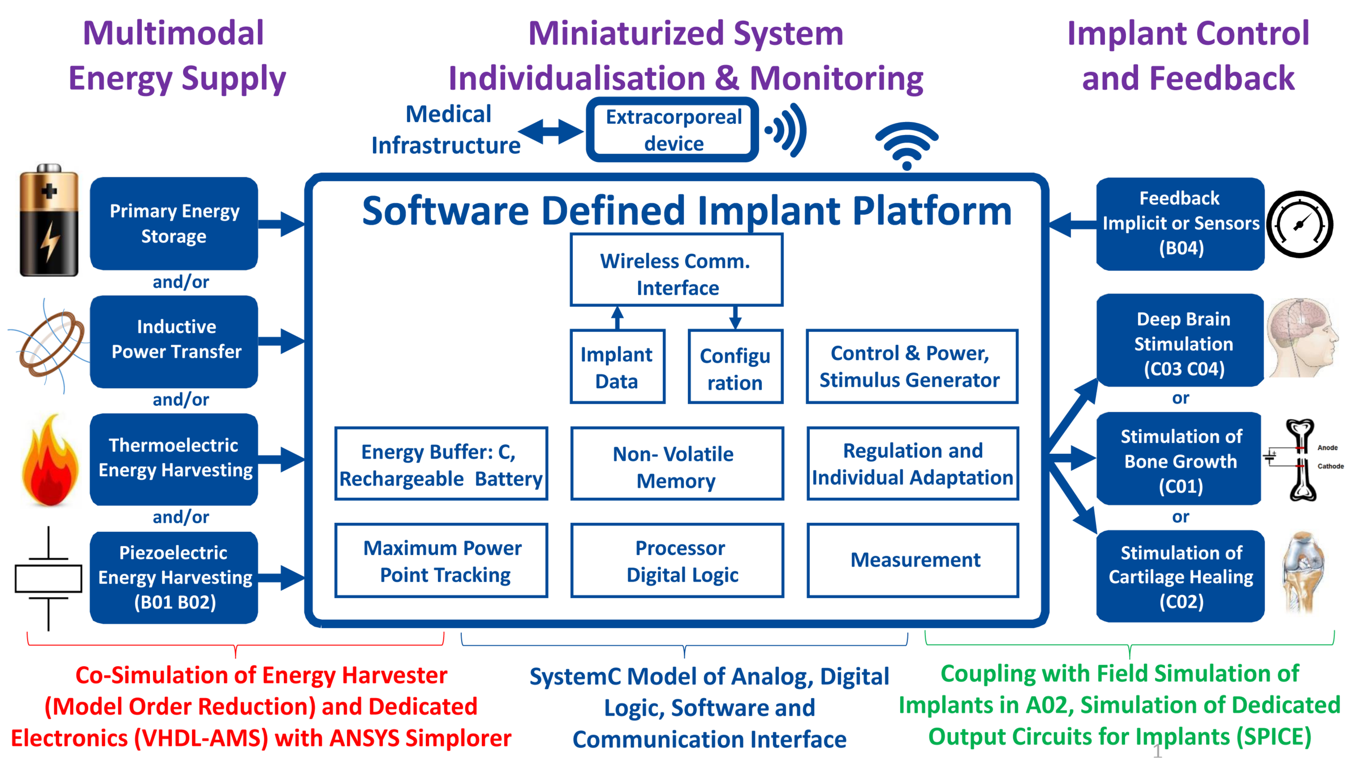


Fig.: Schematic View of SDIP Architecture and Work Overview

Work Packages
- WP1 Analysis of available and demanded energy and information
- WP2 Thermal energy harvesting scenario for subcutaneous energy harvesters
- WP3 Concept and realisation of a thermally optimised implant system
- WP4 Concept, modelling and co-simulation of energy supply sub-systems
- WP5 Concept, modelling and co-simulation of the actual implant and the dedicated SDIP sub-systems
- WP6 Data storage, transmission and interoperability with other medical devices
- WP7 Concept, modelling and simulation of the overall SDIP
- WP8 Discrete SDIP prototype
- WP9 Fully integrated SDIP prototype
- WP10 Comprehensive testing

Thermoelectric Energy Harvesting
- Numerical model of static and dynamic thermal characteristics of body tissue in subcutaneous regions (including heat delivery through blood and convective skin cooling)
- Evaluate the potential of microfabricated thermoelectric energy converters in subcutaneous implant locations by numerical and physical experiments (160..400µW / cm²)
- Novel thermal design for implant housing to resolve the contradictory requirements imposed by the medical implant (e.g. hermeticity, bio-compatibility) and the energy harvesting sub-systems (physical coupling to ambient energy sources).
- Adaptive interconnection scheme of energy harvesters to provide current and voltage levels compatible with power management circuitry under varying thermal power delivery

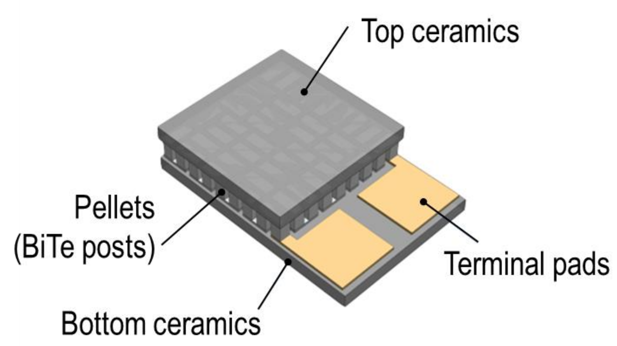


Fig.: High density BiTe pellet integration (TEC Microsystems)

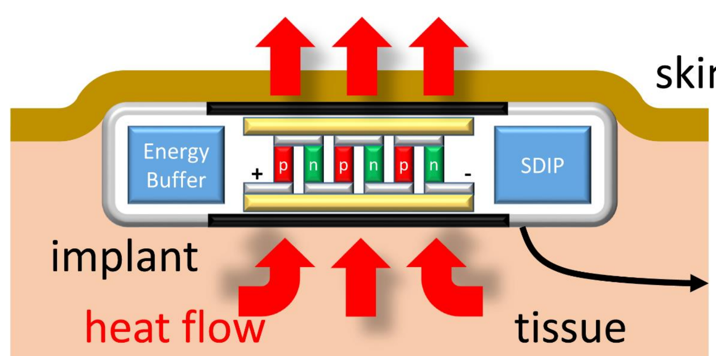
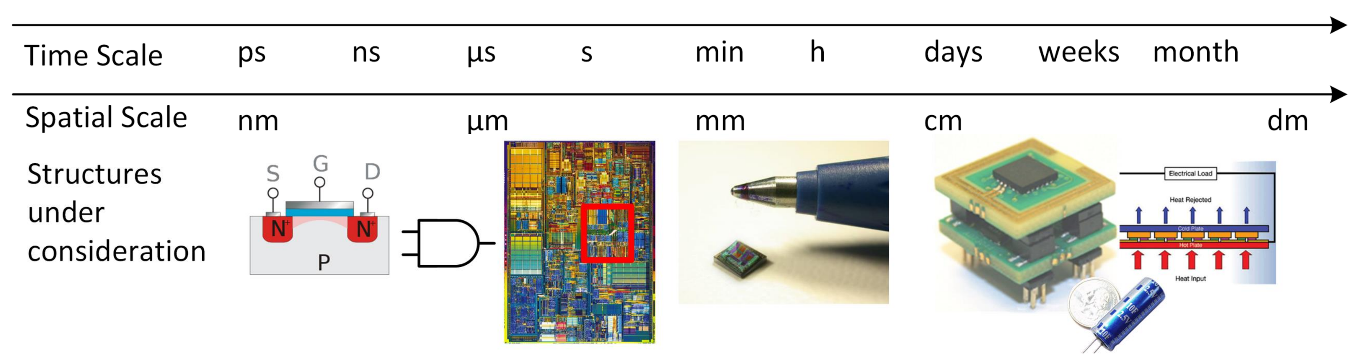
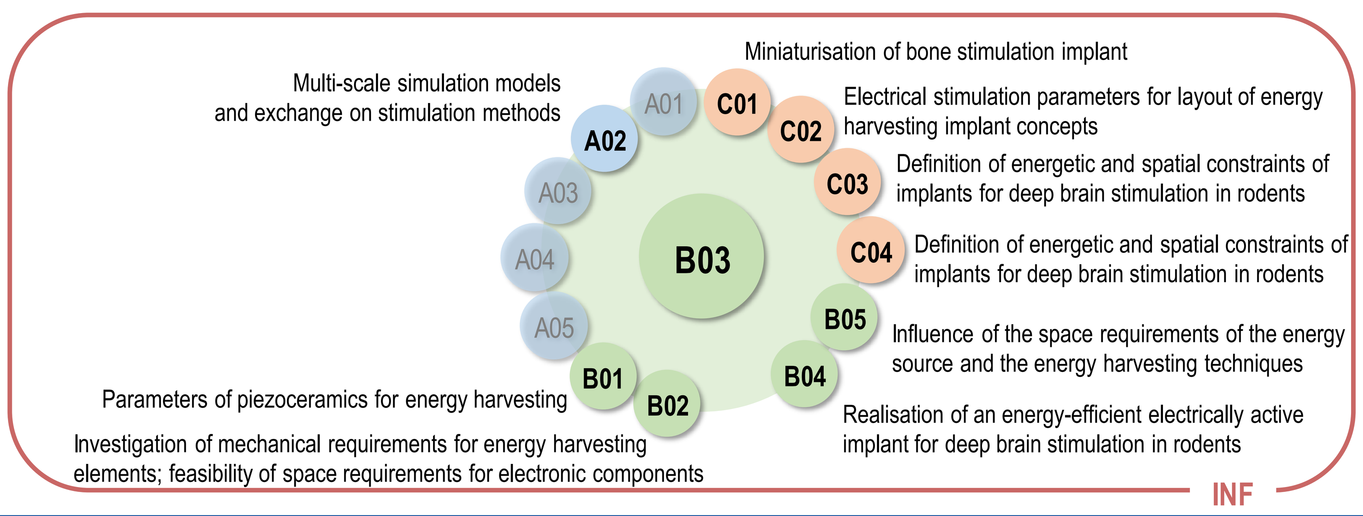


Fig.: Thermoelectric harvesting for subcutaneous implants

Simulation approach
- SystemC and ANSYS Simplorer as system-level simulation environments
- Multiphysical model of energy harvester, implant housing, and surrounding body tissue
- Co-optimisation of different harvesting converters, dedicated power converters and power management is crucial.



Cooperations



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