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Smart hip prosthesis – an overview

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Artificial hip joints are mostly implanted in patients suffering from arthrosis, a widespread disease in modern society. It is generally caused by wear to the joint cartilage, and subsequent damage to the surrounding bone structure, muscles, joint capsules and ligaments. The main symptoms are joint pain and restricted mobility. Older people are at greater risk of developing arthrosis which means that, given the current demographic trends, there are an increased number of people requiring artificial hip replacements.

The hip prosthesis being developed by Fraunhofer researchers as part of the Fraunhofer Lighthouse Project Theranostic Implants is equipped with electronic sensors and actuators that enable the physician to monitor the fit of the artificial hip joint and the bone ingrowth without further surgical intervention, and to readjust the position of the implant if necessary. Conventional prosthetic hip joints have a tendency to work loose because they are unable to adapt to changes in the bone structure. This usually means that they have to be replaced after ten to fifteen years. But hip revision surgery is a complicated medical procedure and carries with it a high risk to the patient's health.

The presentation is about the status of the development focusing on specific components, modules and solutions addressing a new type of hip prosthesis integrating sophisticated sensor and actuator functionalities as well as an first idea of how to potentially use it in practice.

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Overview on an implantable multi sensor system for cardiovascular monitoring

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Continuous monitoring of physiological parameters in cardiovascular areas allows early detection of critical conditions which may lead to clinical symptoms and hospitalization, if not treated in time. Thereby early diagnostics, optimization of therapy and reduction of therapy costs can be achieved. Therefore, the focus on research lies on the development of highly miniaturized smart and implantable sensors with an appropriate encapsulation for long-term applications.

The concept of the presented multi sensor implant utilizes, amongst others, capacitive pressure sensor elements (monolithically integrated in a CMOS process), activity and inclination detection elements and a temperature sensor unit. Thus, additional information about the patient are obtained. Those results are used for side effect compensation which enables a more accurate pressure measurement. Sensor chips, passive components and an antenna coil for telemetric energy and data transmission are integrated in only one Low Temperature Cofired Ceramic (LTCC) circuit board. An inductive near-field coupling at a frequency of 13.56 MHz is used.

Most implantable and medically approved systems are encapsulated by biostable metals such as titanium. Since these popular materials limit further miniaturization of implantable sensor systems, this research work also deals with new encapsulation techniques which provide biocompatibility, long-term functionality and show suitable pressure transmission properties. These requirements can be achieved by a three-dimensional passivation of the micromechanical pressure sensor membranes by a stack of very thin layers applied by Atomic Layer Deposition (ALD). These layers show hermetic sealing and high conformity, even on complex topographies. Additionally, a stack of currently developed and medical approved polymers are applied. Thus, the implant obtains a proper shaping which is necessary to prevent for potentially dangerous blood clots caused by the implant itself.

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Controlling of a hand prosthesis using epimysial signals and peripheral nerve stimulation

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Smart implants combine diagnosis and therapy in a single miniaturized system. They are closed loop systems with different sensors and actuators including wireless signal and energy transmission. Under coordination of the Fraunhofer-Institute of Biomedical Engineering (IBMT) the Fraunhofer Lighthouse Project »Theranostic implants« concentrates the technological possibilities of 12 Fraunhofer Institutes to a marketable technology platform. Exemplary three prototypes with high relevance to the market are built up and tested. Almost the whole area of the theranostic implants is covered: (a) skeletal: smart hip prosthesis, (b) cardiovascular: hemodynamic controlling, and (c) neuromuscular: myoelectric control of hand prosthesis with sensory feedback. Demands of these three prototypes show the driving force for the technology development.

The neuromuscular demonstrator is a complete implantable system for functional assistance. To control the hand prostheses intuitive, eight implantable flexible microelectrodes are used for the invasive acquisition of muscle activities. The signals are pre-processed in an application-specific integrated circuit (ASIC). Four-channel electrical neural stimulation gives the patients a sensory feedback. The ASIC generates the stimulation signal depending on the measured grip force. Telemetry module is used for wireless real-time signal transmission and inductive energy transmission including adaptive energy management. Optical and RF communication was characterized. The detection of the desired hand movement was possible after signal processing including pattern recognition as well as signal classification. Three different possibilities for encapsulation are realised and tested: (a) titanium (b) ceramics and (c) multilayer polymer. The whole development and manufacturing process was accompanied by regulatory affairs including quality and risk management.