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Flexible multielectrode arrays as implantable interfaces to the central and peripheral nervous system

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Abstract:

Neural implants need to establish stable and reliable interfaces to the target structure for chronic application in neurosciences as well as in clinical applications. They have to record electrical neural signals, excite neural cells or fibers by means of electrical stimulation. In case of optogenetic experiments, optical stimulation by integrated light sources or waveguides must be integrated on implants. Metabolic monitoring and detection of neurotransmitter concentrations is also part of the research agenda but not yet mature enough for translation in chronic clinical applications. Proper selection of substrate, insulation and electrode materials is of utmost importance to bring the interface in close contact with the neural target structures, minimize foreign body reaction after implantation and maintain functionality over the complete implantation period. Our work has focused on polymer substrates with integrated thin-film metallization as core of our flexible neural interfaces approach and silicone rubber with metal sheets. Micromachining and laser structuring are the main technologies for electrode array manufacturing. Designing applications for implants in the peripheral and central nervous system needs integration of components, the connection of cables and connectors to both, electrode arrays and hermetic packages containing electronic circuitry for recording, stimulation and signal processing. Failure of one of the components or connections stops the function of the whole system. We present an exemplary implant system and discuss state of the art materials and manufacturing techniques as well as prominent failure modes. Thin-film substrates and hybrid combinations with silicone rubber substrates serve as neural interfaces. Adhesion layers have been integrated to obtain long term stability of polyimide-platinum sandwiches. Hermetic packages with dozens of electrical feed-throughs need novel approaches to meet the desire of implants with hundreds of electrode channels. Reliability data from long-term ageing studies and chronic experiments show the applicability of thin-film implants for stimulation and recording and ceramic packages for electronics protection. Examples of sensory feedback after amputation trauma, vagal nerve stimulation to treat hypertension and chronic recordings from the brain surface display opportunities and challenges of these miniaturized implants. System assembly and interfacing microsystems to robust cables and connectors still is a major challenge in translational research and transition of research results into medical products.

Biography

Prof Dr Stieglitz is a full professor for Biomedical Microtechnology in the Institute for Microsystem Technology (IMTEK) at the University of Freiburg (Germany). His work focuses on the development of biocompatible assembling and packaging techniques and the application of microsystems for neural prostheses and neuromodulation. His research interests include biomedical microdevices, functional electrical stimulation and neural implants.

Dr Stieglitz studied electrical engineering at the University of Technology Braunschweig (1987-89) and Karlsruhe (1989-93) where he received the Dipl.-Ing. degree in electrical engineering with the special subject biomedical engineering in 1993.

In 1998 he received the Dr.-Ing. degree (summa cum laude) in electrical engineering from the University of Saarland (Germany). This work was honored with the 'Stiftung-Familie-Klee' award for young scientists from the German Society for Biomedical Engineering (DGBMT) in 1999.

In 2000 he received the science award of the Saarland State for his work on flexible, neural prostheses. Dr Stieglitz qualified as a university lecturer (habilitation) in 2002 at the Saarland University in biomedical microsystem technology. He worked with the Fraunhofer-Institute for Biomedical Engineering (IBMT) from 1993 to 2004, where he established the research work on biomedical microsystems for neural prostheses, which finally led to the IBMT Neural Prostheses Group.

Dr Stieglitz is a Senior member of the IEEE Engineering in Medicine and Biology Society (EMBS) where he is member of the Neural Engineering Technical Committee, the German Engineering Society (VDI) and the German Society for Biomedical Engineering (DGBMT) within the German Electrotechnical Society (VDE) where he is chair of the Neural Prostheses and Intelligent Implants Section. He is also member of the Society for Neurosciences, the Materials Research Society and founding member of the International Society for Functional Electrical Stimulation (IFESS).

He is co-founder and of the companies Cortec (www.cortec-neuro.com) and neuroloop (www.neuroloop.de) that were spun off the University of Freiburg. Dr. Stieglitz is member of the Bernstein Center Freiburg and deputy speaker of the Cluster of Excellence BrainLinks-BrainTools (German Research Foundation ExC 1086).