Application of microsystem technology for medical implants

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Microsystems containing **microelectrode arrays integrated** in flexible substrates are often used as components of medical implants for electrical stimulation of nerves or recording of neural signals. ***We present examples of microelectrodes for hearing and visual implants developed in the frame of the Healthy Aims project***. The structures have been designed in collaboration with partners developing medical products: Cochlear Technology - responsible for development of Cochlear Implant and Intelligent Medical Implants - responsible for development of Retina Implant.

The retinal and cochlear implant systems have a modular design and consist of a few main components: stimulators implanted in the body, external vision or hearing interfaces and external pocket processor, which translate sound or image information into stimulation commands. The stimulators are implantable heterogeneous microsystems build of flexible matrix of stimulation electrodes and a receiver comprising of several electronic components including an antenna and ASICs.

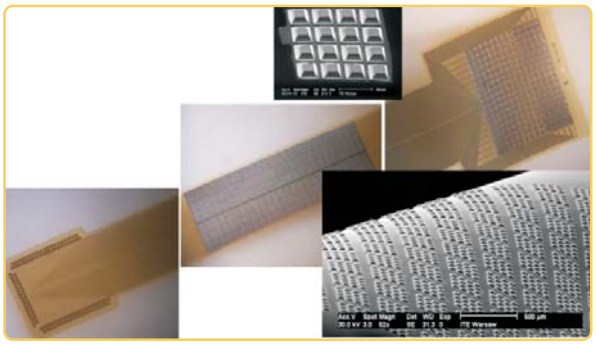

Fig. 1 The test structure of retina microelectrode manufactured at ITE, insets show a dense matrix of 3D stimulation electrodes.

A microelectrode developed for retina implant is built of a planar polymer foil integrated with circuit paths, metal electrodes, and bonding pads. This structure serves as both the stimulation interface and the multilayer flexible circuit board for assembling electronic components. The matrix of 252 electrodes consists of 4032 3D-shaped stimulation sites to increase the electrode surface area to enable more energy to be applied to the nerves

Two types of microelectrodes are developed in ITE for hearing implants: passive cochlear microelectrodes and modiolus microelectrodes. The conventional intra-cochlear microelectrode interacts with the spiral ganglion cells in the cochlea, while the modiolus microelectrode inserted in the nerve bundle enables more direct coupling between the stimulation electrodes and the cochlear nerve. The modiolus microelectrode improves the restoration of hearing (more stimulation electrodes can be used) and could reduces the power requirement for the implant by decreasing stimulation thresholds. The passive cochlear electrode manufactured in ITE has consisted of 22 Pt stimulation sites connected with bonding pads using 2μm thick Pt strips. The platinum structure has been coated with 120μm thick parylene-silicone layers. The modiolus electrodes have been manufactured in ITE using double side bulk micromachining technology. The Pt stimulation electrodes have been arranged in a single row on a straight silicon beam. To facilitate the monitoring of beam deflection during the surgical insertion of these electrodes, a piezoresistive deflection sensor has been designed at the base of the cantilever beam. The structure has been entirely isolated with double parylene-silicone coating.

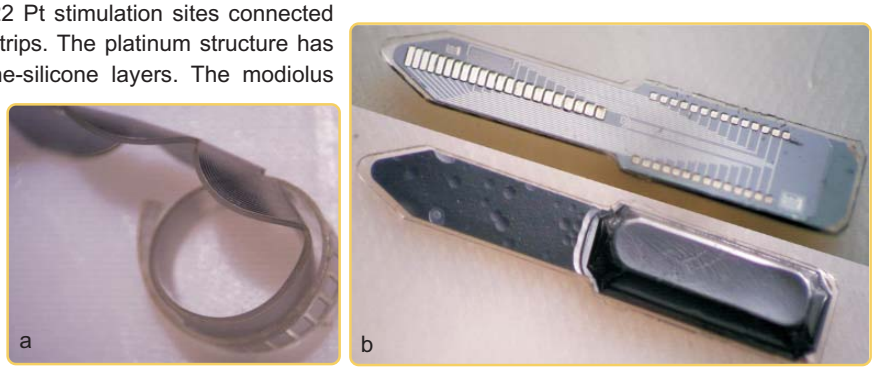

Fig. 2 Examples of electrodes for hearing implants: a) passive cochlear microelectrode containing 22 Pt stimulation sites coated with silicone rubber, b) silicon modulus electrode integrated with a piezoresistive deflection sensor and protected with parylene-silicone coating

Implantable devices, in order to be safely inserted into a human body and remain there for many years, must be constructed with use of materials that are biocompatible or must be isolated form the body with a biocompatible coating. One of the materials, which has been used for construction of implanted flexible electrodes is a silicone rubber. The advantages of this material are good mechanical properties (high tensile strength and superior flexibility) and its biocompatibility. The shape of silicone structures is usually formed by use of injection molding process supported by laser ablation but more precise pattern may be defined in silicone using plasma etching and thus ITE has developed a process of deep plasma etching of silicones. Plasma treatment and other technological operations, however, can change physical and mechanical properties of the silicone layer and can also induce specific biological responses when a device is placed in the body. Therefore, plasma treated silicone layers has been investigated using XPS analysis, wetting and cytotoxicity tests. The formation of a top layer rich in plasma originated fluorine has been detected but silicone surface has preserved its hydrophobic properties after plasma processes. Moreover, the cell viability on a raw and plasma treated silicone has been found to be high. The morphology of silicone layer has been examined as well using SEM analysis. Hardly removable grass-like etching residues have been observed. Its formation has been found the main disadvantage of plasma processing since the residues cannot be easily removed from the surface of the stimulation electrode. It has been found that the post-etch residues can be decrease or even eliminate completely by increasing the temperature of the wafer etched in plasma.

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