Integrated high-resolution nano-modified multi-electrode arrays (InMEAs)

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Macroelectrodes for stimulation of nerve cells or recording of action potentials are widely used today. Examples of clinical applications are cardiac pacemakers, cochlear implants or deep brain stimulators. In contrast, microelectrodes are typically applied in so called microelectrode arrays (MEAs) which are mainly used in medical and biological research. For cardiac peacemaker a further electrode miniaturization is not mandatory. But in case of cochlear implants or retinal implants the use of microelectrodes would bring a significant progress by increasing the numbers of electrodes. Electrode miniaturization is only reasonable when improving the electrical and electrochemical properties at the same time. To reach this objective the approach within InMEAs will be the nanomodification of the electrodes.

One subproject within InMEAs is to build up an “intelligent electrode”. That means the integration of the necessary microelectronic chip for stimulation into a flexible carrier in close proximity to a group of stimulation electrodes.
The flexibility has the great advantage that subsequent implants can be better adapted to the properties of a human body. In addition, the number of microelectrodes can be increased by connecting these “intelligent electrodes” to a bus system (compare figure 1).

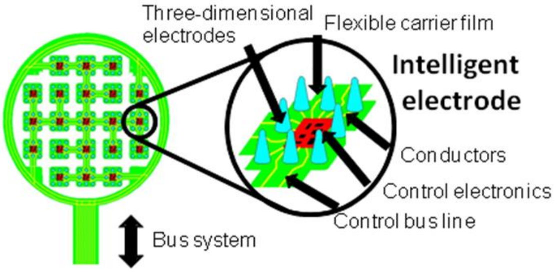

Fig. 1: Flexible microelectrode array with distributed electrodes and distributed control electronics

The flexibility of the CMOS-chips will be reached by thinning them to thicknesses below 20 µm. These flexible CMOS-chips, gold conductors and each of 25 microelectrodes will be integrated in a polyimide carrier and encapsulated with parylene. This structure is called BASIS-FLEX-MEA, shown schematically in figure 2.

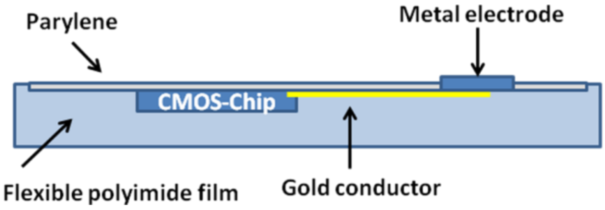

Fig. 2: Schematic representation of the BASIS-FLEX-MEA

The electrodes are made of iridium oxide, shown in figure 3. Iridium oxide is already used by many research groups worldwide, since it is best suited for stimulation of nerve cells with a charge-transfer capacity over $90 mC/cm^2$ [1-5].

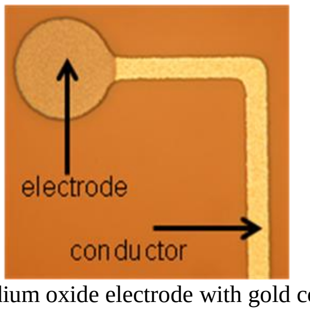

Fig. 3: Iridium oxide electrode with gold conductor

To further improve, they will be coated with Carbon Nanotubes (CNTs). This is done in order to increase the charge transfer capacity even more. In addition, the cell growth on CNTs is reported to be very excellent [6]. Unfortunately, vertical CNTs cannot be deposited directly on the electrodes because the polyimide is only stable up to 400°C. But in the moment the deposition of vertical CNTs requires 700°C. The challenge now lies in the development of a transfer process for the deposition of vertical CNTs on the electrodes. Alternatively, CNTs will directly be deposited onto the electrode surface electrochemically out of a suspension.

As a result of the project a demonstrator will be presented which will serve as a basic unit for the “intelligent electrode”. A flexible CMOS-chip embedded into polyimide will control 25 electrodes (compare figure 1 and 2).

In the second subproject a high-resolution highly-integrated CMOS-based microelectrode array for medical studies of cells and tissue sections will be developed. This so called BASIS-CMOS-MEA is shown schematically in figure 4.

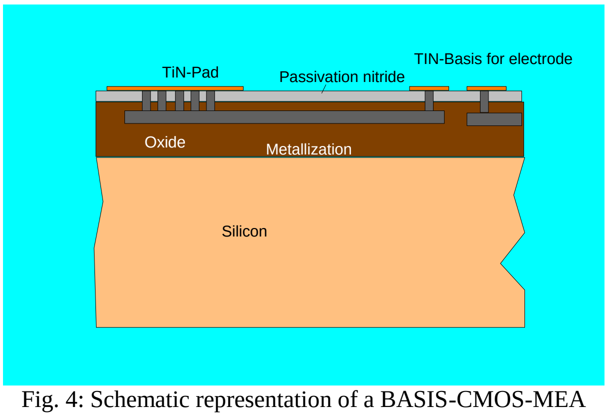

Fig. 4: Schematic representation of a BASIS-CMOS-MEA

As in the first subproject the electrodes will also be coated with CNTs in order to increase the charge transfer capacity.

The structure shown in figure 4 exhibits a plane surface topology and can be used as a flexible platform for the integration of the CNTs on a CMOS circuitry.

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Project partners

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References

[1] Wessling, B., Besmehn, A., Mokwa, W., Schnakenberg, U., „Reactively sputtered iridium oxide – influence of plasma excitation and substrate temperature on morphology, composition and electrochemical characteristics", Journal of the Electrochemical Society 154(5), 2007, F83-F89

[2] Wessling, B., Mokwa, W., Schnakenberg, U., „Sputtered Ir Films Evaluated for Elektrochemical Performance I. Experimental Results", Journal of Electrochemical Society, 155 (5) F61-F65 (2008)

[3] Butterwick, A., Huie, P., Jones, B.W., Marc, R. E., Marmor, M. and Palanker, D., "Effect of shape and coating of a subretinal prosthesis on its Integration with the retina", Experimental Eye Research 88(1), 22-29 (2009)

[4] Roessler, G., Laube T.; Brockmann C et al. „Implantation and Explantation of a Wireless Epiretinal Retina Implant Device: Observations during the EPIRET3 Prospective Clinical Trial. INVESTIGATIVE OPTHALMOLOGY & VISUAL SCIENCE, 50 (6): 3003-3008; 2009

[5] Shire, D.B., Kelly, S.K., Chen J.H., Doyle, P., Gingerich, M.D., Cogan, S.F., Drohan, W.A., Mendoza, O., Theogarajan, L., Wyatt, J.L. and Rizzo, J.F., "Development and Implantation of a Minimally Invasive Wireless Subretinal Neurostimulator", IEEE Transactions on Biomedical Engineering 56(10), 2502-2511 (2009)

[6] Gabay, T., Jakobs, E., Ben-Jacob, E., Hanein, Y., „Engineered self-organization of neural networks using carbon nanotube clusters", Physica A350 (2005) 611-621