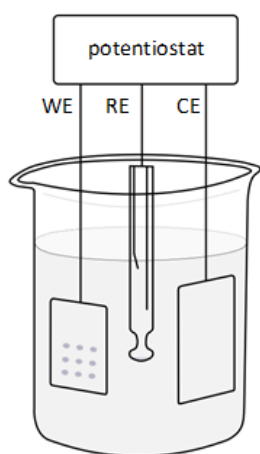


Electrical Characterization of Implantable Neural Interfaces

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In recent decades, bioelectronic medicine has become increasingly important for the development of therapies or the diagnosis of neurological diseases. The stimulation of neuronal tissue is an application of targeted electrical signals that has already been successfully used to treat various neurological diseases or to alleviate their symptoms. There are a wide variety of neural interfaces in research and on the market for this purpose that come into contact with the central or peripheral nervous tissue either directly or indirectly.

One kind of neural interface, developed and manufactured by CorTec GmbH, consists of a polydimethylsiloxane (PDMS) base as an insulating material and platinum iridium (PtIr) as a contact material. The contact material, as well as the design and manufacture of the electrodes, help define the mechanical and functional properties. The functional properties can be determined by electrochemical characterization of the exposed contact areas and transferred to subsequent application parameters.



Electrochemical Impedance Spectroscopy

Determining the possible charge transfer of a contact material is one form of characterization. The charge transfer and the associated electrical behavior of an electrochemical system can be described using equivalent circuit diagrams, which simplify the complexity of real circumstances and can be approximated by already known theories and models. Probably the most common basis for translating the results is the Randels cell as a model.

Figure 1 Three-electrode measurement set-up to determine the electrochemical properties of the neuro electrodes.

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In electrochemical impedance spectroscopy (EIS), a working electrode, a counter electrode and a reference electrode are immersed in an electrolyte. As soon as a sinusoidal alternating voltage is applied to the working electrode with reference to the OCP, a current flows from the working electrode to the counter electrode. The impedance and frequency response of the working electrode depend on the surface structure and material. In order to avoid irreversible Faraday reactions at the working electrode, alternating voltages with an amplitude lower than 50 mV_{pp} are applied.

In impedance spectroscopy, the impedance of the entire system is considered. Theoretical principles show that the impedance of a (working or counter) electrode in an electrolyte is lower the greater the capacitance. The capacitance increases with the surface area of the electrode. Therefore, the larger the surface the counter electrode, the smaller the contribution of the counter electrode to the measured impedance. If a counter electrode with a sufficiently large surface area is selected, its contribution to the impedance can be neglected. The surface area of an electrode immersed in an electrolyte increases with the porosity of the surface. This means that the so-called “chemically active area” can vary while the geometric area remains the same. The lower the overall impedance curve, the larger the active area.

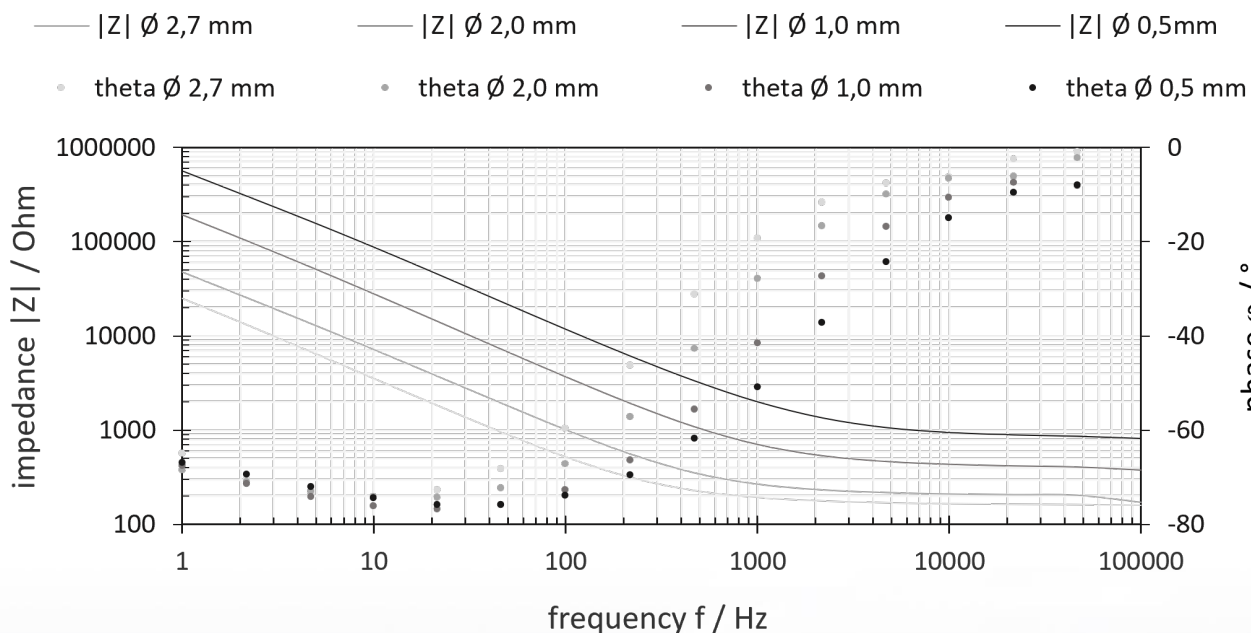


Figure 2 Recorded impedance spectra of four different PtIr contact sizes with a 3-electrode measurement setup with platinum counter electrode and silver-silver chloride reference electrode with a prediction voltage of 10 mV.

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Cyclic voltammetry and determination of charge storage capacity

The structure of the measurement of a cyclic voltammetry (CV) is similar to that of an EIS measurement. The voltage at the working electrode is moved between two voltage limits at an appropriate rate of change in reference to the OCP. The activation energy for Faraday reactions at the electrode-electrolyte phase boundary is provided by an electrical voltage between the electrolyte and the electrode. Different reactions require different activation energies and generate different currents. Conclusions can therefore be drawn from the CV about the type of reactions on the electrode surface which gives an idea about contamination on the surface or material changes. The determination of the CV of an electrode contact should always be within the water window of the respective contact material (in this case PtIr). The individual peaks of the recorded curve are material-specific.

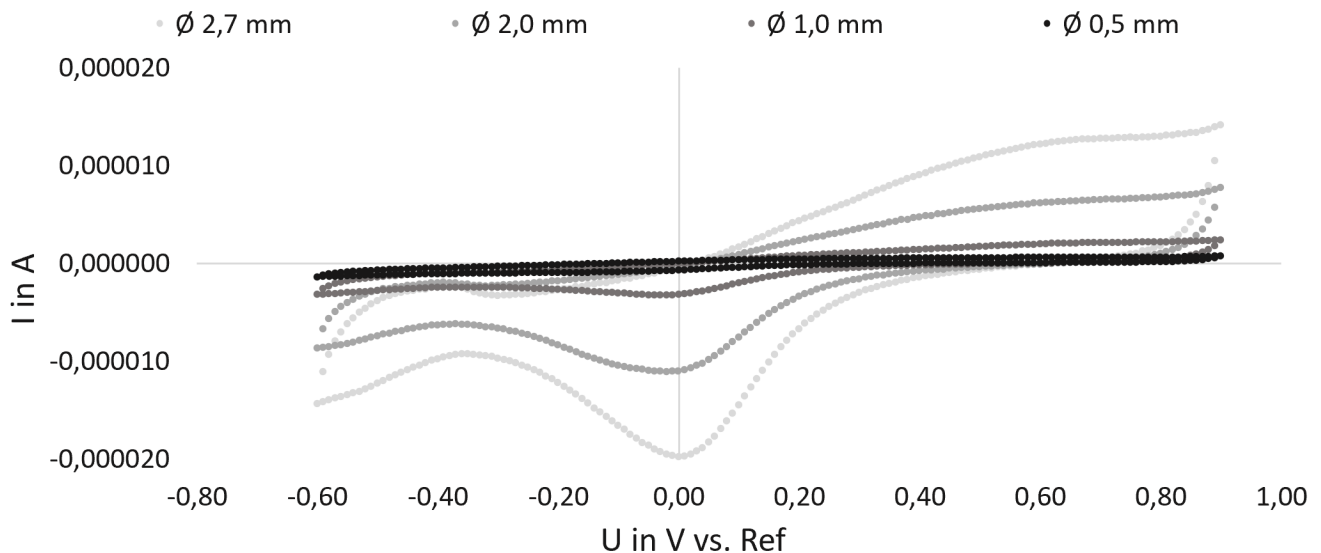


Figure 3 Recorded voltamogram of four different PtIr contact sizes with a 3-electrode measurement setup with platinum counter electrode and silver-silver chloride reference electrode between -0.6 V and 0.9 V with a sampling rate of 200 mV/s.

From the CV of the electrode material, the charge storage capacity (CSC) can be calculated, which indicates how much charge can be stored in the electrode material before hydrolysis begins. The charge storage capacity is defined by the electrochemically active surface and the material properties themselves. The total charge storage capacity is calculated by integrating the measured current density over the discharge time. The calculation includes the area within the recorded current curve within the voltage range. With the Gamry Framework software, this can be done directly using the “Integration” function. The larger the electrochemically active electrode surface, the larger the area within the recorded CV diagram.

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