INVESTIGATION OF ELECTROCHEMICAL BEHAVIOR OF STIMULATION/SENSING ELECTRODE MATERIALS - II. RuO_2- AND IrO_2-COATED ELECTRODES

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During artificial stimulation of the heart muscle, one of the important processes is the conversion of electric current in the electrode to ionic current in the body. The conversion takes place on the electrode surface and in the electrode/electrolyte boundary, through several different interfacial processes. Most of the pacing mechanisms are of electrochemical nature.

A few metal oxides exhibit metallic electric conductivity, excellent chemical stability, and pseudo-capacitive properties. Therefore they are of interest for stimulation/sensing electrode applications. For RuO_2 and IrO_2 electrodes, two main mechanisms are responsible for the total charge injection during stimulation. In addition to the charging/discharging of the double layer, redox reactions , i.e., oxidation-reduction of the oxides, will also contribute to the charge injection. In this study, electrochemical processes occurring on RuO_2- and IrO_2-coated electrodes in a PBS solution were investigated by using combined cyclic voltammetry (fast CV, between –3 V to 1 V vs. open-circuit potential) and electrochemical impedance spectroscopy (EIS). The samples (supplied by W. C. Heraeus GmbH & Co. KG) were produced by sputtering deposition of the oxides on Ti substrates. SEM pictures (Fig. 1a and 1b) show the homogeneously covered surface of the electrode samples as received.

CV measurements show that the reactivity of the RuO_2-coated electrode decreases with the potential cycling, probably due to oxidation of Ti in defects of the RuO_2 coating. The absence of redox peaks in the CV curves with high scan rates indicates that double layer charging /discharging is the dominant charge transfer mechanism. On the other hand, the CV curves with lower scan rates show anodic and cathodic peaks of the redox reaction of the oxide.

The first cycle of the IrO_2-coated electrode exhibits two anodic and two cathodic peaks, due to the transition between different oxidation states of Ir. These peaks disappear during the later CV cycles and, instead, one rather large anodic peak appears, probably due to oxidation of the Ti substrate. SEM pictures of the electrode show a cracked surface of IrO_2 (Fig. 1c and 1d). Likely the cracks have penetrated down to the Ti substrate since the IrO_2 coating is very thin (ca. 2 μm).

EIS results from the RuO_2- and IrO_2-coated electrodes reveal that, depending on the scan rate, the materials are affected by the CV cycles, see e.g., in Fig. 2. Some of the changes may be attributed to the oxide formation on Ti substrate. However, the drastic decrease in polarisation resistance could be due to hydrogen loading in the oxide or the substrate, as supported by cathodic polarization experiments.

Figure 1. SEM photos of (a) RuO_2, (5000:1 magnitude), and (b) IrO_2, (10000:1), before CV. (c) IrO_2, (100:1), after 1000 cycles of CV at 1700 mV/s. (d) Enlargement (4000:1)of dark area in (c).

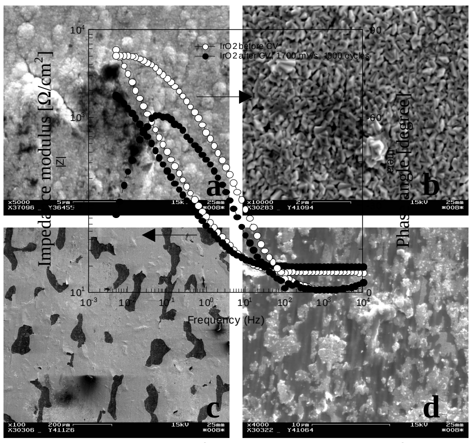

Fig. 2. EIS spectra of IrO_2 electrode before and after 1000 cycles of CV at 1700 mV/s.