INVESTIGATION OF ELECTROCHEMICAL BEHAVIOR OF STIMULATION/SENSING ELECTRODE MATERIALS - I. Pt, Ti, AND TiN-COATED ELECTRODES

A. Norlin[1,2], J. Pan[1], C. Leygraf[1]
[1] Div. Corrosion Science, Dept. Materials Science and Engineering, Royal Institute of Technology Drottning Kristinas väg 51, SE–100 44 Stockholm, Sweden
[2] St. Jude Medical AB, Veddestavägen 19, SE-175 84, Järfälla, Sweden

Material design for stimulation/sensing electrodes in cardiac applications is a multifaceted problem. The material has to be biocompatible in the biological environment, able to transfer the electrical stimulation and sense the cardiac response, and stable enough to maintain its function through the lifetime of the implant. Moreover, surface structure of the electrode and characteristics of the electrode-electrolyte (body fluid) interface are important for fixation of the electrode in the tissue and the electrochemical behavior. Electrochemical processes occurring at the electrode-electrolyte interface are of ultimate importance for the electrode performance.

Progress in material processing and coating technologies enables the fabrication of materials with a well-defined stoichiometry and surface structure. This gives a range of new potential materials for electrochemical stimulation/sensing applications. In this paper, a combination of electrochemical and surface characterization methods is used to investigate electrochemical behavior and long-term stability of Pt, Ti, and TiN-coated electrode materials in a simulated physiological solution. The methods are also used for investigation of new potential electrode materials, and the results will be reported in separate paper.

Cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) were used in order to determine the processes taking place on the electrode surface during cardiac stimulation/ sensing. Fast CV with a large number of cycles was performed at different sweep rates in the potential range from –3V to 1V vs. open-circuit potential to account for processes occurring at different time scales. EIS was performed both before and after the CV experiments (simulated aging) of the material to detect irreversible changes in the interfacial characteristics. Simulated stimulation pulses were applied to the electrode and the response analyzed. All electrochemical measurements were performed in a phosphate-buffered solution (PBS), with Na^+, K^+, PO_4^{2-} and Cl^- contents similar to those of blood. Changes in the surface microstructure were characterized by scanning electron microscopy (SEM), and changes in the surface composition were analyzed by X-ray photoelectron spectroscopy (XPS).
The CV curves obtained indicate that different reactions (hydrogen-plating, hydride formation and oxidation, oxide formation and reduction, etc.) occur on the Pt surface. On Ti, the oxide formed is not completely reduced under cathodic potentials. The dominating process on the TiN-coated electrode is the charging and discharging of the electric double layer. Fig. 1 shows CV curves obtained for Pt at 1700mV/s. The sweep rate has a significant influence on the processes. EIS measurements reveal that the polarization resistance decreased and the interfacial capacitance increased after the CV experiments. Fig. 2 shows EIS spectra for Pt before and after CV with different sweep rates, which indicate that the CV cycles caused a significant decrease in the polarization resistance.
Figure 1. CV curve for Pt in the PBS solution.
Figure 2. EIS spectra for Pt in PBS solution before and after the CV cycles.