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Electrodeposited Iridium Oxide
EIROF

Low Impedance Coatings for Neural Stimulation and Recording Electrodes

Background

Thin films of electrodeposited iridium oxide (EIROFs) are useful as low-impedance coatings for neural stimulation and recording electrodes. With iridium oxide, charge is injected into tissue by reversible reduction and oxidation reactions that minimize electrode polarization and avoid electrochemically irreversible processes that may damage either the electrode or tissue. The use of iridium oxide as a neural stimulation electrode was first describe in 1983 [1]. Since then, iridium oxide has been used in animal studies for stimulation of the spinal cord [2], the cochlear nucleus [3], and in many studies of cortical stimulation [4]. Microstimulation in the human occipital cortex using iridium oxide electrodes has also been described [5].

EIC Biomedical has introduced a process for electrochemical deposition of iridium oxide onto metal electrodes suitable for neural stimulation and recording [6]. The electrodeposited iridium oxide (EIROF) is similar in behavior to activated iridium oxide (AIROF).

EIROF can be deposited on the following:

- Gold,
- Platinum,
- Platinum-iridium alloys,
- Stainless steel (316LVM),
- Carbon

Typical range of substrate geometries:

- Electrode area: ~50 μm^2 to >25 cm^2
- Electrode shape: no restriction

Suitable electrode structures:

- Wires
- Metallized flexible polymers
- Metal ribbons
- Micromachined silicon

Electrochemical Characteristics

The thickness of EIROF is usually reported as the charge per unit area associated with the reaction $Ir^{3+} \Leftrightarrow Ir^{4+} + e^-$. The charge is measured from the time integral of the cathodic current flow during a slow-sweep-rate cyclic voltammogram and is called the cathodic-charge-storage-capacity (CSC_c). Adherent EIROF can be deposited with a CSC_c of at least 30 mC/cm^2 on most suitable metals.

An example of a cyclic voltammogram (CV) of EIROF deposited on a platinum electrode is shown in Figure 1. The CV was acquired in phosphate buffered saline (PBS) at a sweep rate of 50 mV/s. The EIROF has a CSC_c of 25 mC/cm^2.

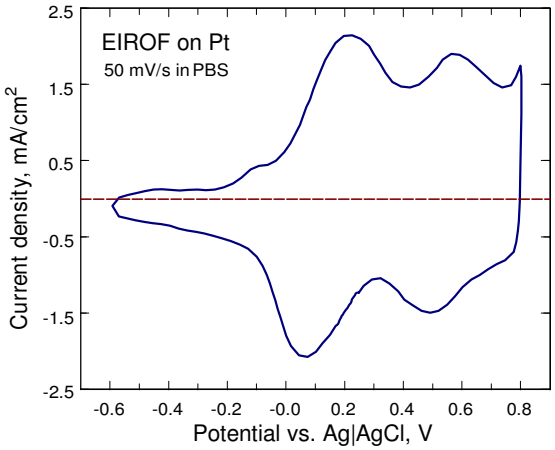

Figure 1. Cyclic voltammetry of EIROF on platinum

The impedance of 25 mC/cm^2 CSC_c EIROF measured in PBS over a frequency range of 0.05 Hz to 10^5 Hz is shown in Figure 2. The impedance modulus decreases by a factor of ~10 at frequencies of 10^3 Hz or lower. Electrode impedance depends on the size of the electrode and CSC_c of the EIROF coating and should be determined experimentally for individual electrode designs.

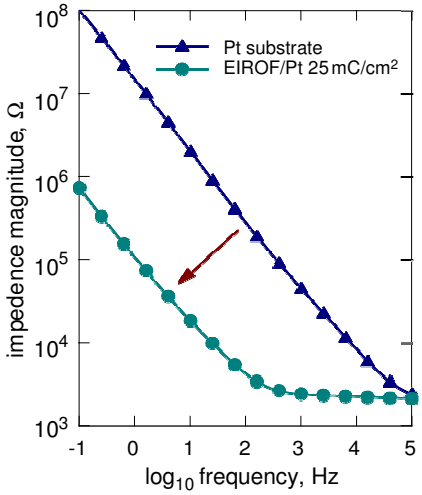

Figure 2. EIROF reduces the impedance of platinum electrodes

Charge Injection Capabilities

Activation of neural tissue is typically obtained with short-duration current pulses. At neural stimulation pulse parameters and electrode areas, EIROF is similar in performance to AIROF [6]. EIROF charge-injection capacity ranges from 1-3 mC/cm^2 with 0.2 ms pulses depending on pulse parameters and the use of a positive potential bias in the interpulse period. EIROF has been subjected to 30 x 10^6, 1.2 mC/cm^2 charge injection pulses with <10% loss of CSC_c.

Polarization

Electrode polarization during current pulsing is greatly reduced by EIROF coatings. Reduced polarization decreases power requirements for delivering stimulation pulses, avoids irreversible and potential harmful reactions at the electrode-tissue interface, and permits recording of evoked activity with stimulation electrodes.

Electrochemical Characterization

At EIC Biomedical, detailed electrochemical characterization of EIROF coatings is performed to ensure quality and compliance with customer specifications. The characterization includes:

Cyclic Voltammetry - determines the quantity of EIROF on an electrode.

Impedance Spectroscopy - assesses the recording and sensing performance as a function of frequency as well providing an indication of charge-injection capability.

Charge-injection Capacity - voltage transients are measured during stimulation pulsing to determine EIROF polarization, which is then compared with established polarization limits for avoiding electrode damage or harmful irreversible reactions at the electrode.

Microscopy - Optical and scanning electron microscopy are used to determine the morphology and uniformity of EIROF

EIROF Stability

EIROF tolerates sonication and repeated drying and rehydration, provided electrolytes are thoroughly washed with distilled or deionized water before drying. EIROF is resistant to strong acids, bases, and solvents. Long-term stability studies of EIROF electrodes are conducted at EIC Biomedical to establish performance and stability using puls ing conditions relevant to the intended research or clinical use of the electrodes.

Sterilizing EIROF

EIROF is sterilized in ethylene oxide or by autoclaving. EIROF should not be subjected to dry heat over 125°C.

Storing EIROF Electrodes

EIROF electrodes can be stored dry indefinitely but may require some period of electrolyte immersion to obtain their low impedance state if subjected to elevated temperatures during dry storage. EIROF may also be stored wet in distilled water, saline, or buffered saline.

EIROF Coatings at EIC Biomedical

EIC Biomedical works with sponsors to develop EIROF coatings for their electrodes. This service includes:

- Initial assessment of the suitability of EIROF for the intended application;
- Selection of EIROF deposition parameters;
- Coating of sponsor-supplied electrodes;
- Electrochemical characterization and long-term pulsing and stability studies.

For more information about EIROF, please contact us at:

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Limitations

The suitability and safety of EIROF coatings for any intended application is the responsibility of the end-user. EIC Biomedical does not guarantee the performance of EIROF coatings supplied by the company. The end-user is cautioned that the long-term stability and performance of EIROF will vary with the material, geometry and size of coated substrates, on the manner in which the EIROF is used, the medium in which the EIROF is used; and other factors that may not be readily predicted.

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