

Deposition and Characterization of Ruthenium Films for Neural Electrodes

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Abstract:

Neural probes are used to stimulate neurons or record electrical signals, which can be instrumental in understanding the neural network and treating disease. Platinum and iridium are currently used as the electrode material, but ruthenium has promising properties. It is important that materials have high charge storage capacity and low impedance. We investigated the deposition of ruthenium oxide films on gold, titanium nitride, platinum, and atomic layer deposited ruthenium. The samples were characterized using cyclic voltammetry and impedance spectroscopy to predict their performance for neural probe applications.

Introduction:

Neural probes interface electrical stimulation with biological tissue such as neurons. These probes can be used to stimulate or to record the activity of the neurons. Applications of the probes include deep brain stimulation for Parkinson's disease, epilepsy, and depression [1, 2].

Neurons can be stimulated by creating a functional response by depolarizing membranes of excitable cells through the injection of current from the probe. This creates a flow of ionic current between two or more electrodes, one which is near tissue. Neural activity can also be recorded by micro-probes by measuring the potential created by neuron membrane depolarization. Current probes are made of platinum (Pt), iridium oxide (IrO_2), and titanium nitride (TiN) [1, 3, 4].

For stimulation, probes must be able to send a charge-balanced waveform to avoid damage to the electrode and surrounding tissue [1]. Chemically, probes must be bio-compatible. Any reactions that occur at the electrode surface must not release harmful molecules into the body or degrade the electrode so that performance is affected. Neural probes should be small in size to be less intrusive in the brain tissue [1].

The goal of this project is to improve the electrical performance of neural probes by plating ruthenium (Ru) metal onto possible probe substrates. It is worthwhile to investigate the use of Ru because it has more reduction-

oxidation states and could provide a better interface with tissue. An increased number of states may correspond to a greater charge injection, which would be useful for brain stimulation. Ruthenium also shares similar biocompatibility and corrosion resistance properties to other currently successful materials [5].

Deposition Methods:

Electrochemical deposition is selective and a very small area can be plated. In this report, electrochemical deposition was used to deposit Ru on multiple substrates to investigate its usefulness for improving neural probes.

To deposit Ru onto different substrates, a three probe setup was used with a potentiostat (Autolab Booster 20 A). A Ag/AgCl reference electrode and platinum counter electrode were used. Ruthenium was deposited using constant voltage deposition, and constant current deposition at varying magnitudes and for various times. Two electrolytes were investigated: $(\text{Ru}(\text{NO}_2))_2(\text{SO}_4)_3$ and RuCl_3 . In some samples, the electrolyte was heated to approximately 60°C to increase the kinetics of the solution.

Several substrates were used for deposition: gold (Au), platinum (Pt), titanium nitride (TiN) and titanium nitride treated with hydrofluoric acid (TiN HF). Atomic layer deposited ruthenium (ALD Ru) was used as a control.

