Precious Metals for Implantable Electrodes

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Implantable electrodes encompass a variety of devices that impart an electrical signal to body tissue, or record nerve signals sent by the body, with some newly marketed bioelectrodes even capable of both roles. Since the introduction of the cardiac pacemaker, implantable electrodes have become acceptable medical treatments for epilepsy, Parkinson's disease, diabetes, arthritis, paralysis, and pain modulation, amongst many others.[1] Research continues to improve upon these available treatments while developing new implantable electrodes with objectives like vision repair, diabetes modulation, and rheumatoid arthritis relief.

The success of an implantable electrode is strongly influenced by the choice of electrode material, as there are a number of material characteristics to consider: electrical and thermal conductivity, biocompatibility, stability, radiopacity, and machinability. Precious and noble metal alloys exhibit a number of these imperative characteristics making them long-time favorites for successful implantable electrode design.

Metal alloys like platinum and platinum-iridium are often chosen for implantable electrodes due to their electrical conductivity and charge injection capabilities. High charge injection capacities (CIC) allow for smaller electrodes that can still inject appropriate charges without causing adverse chemical reactions. Optimal electrode materials have high CIC values and low impedance values, together enabling the continual miniaturization of implantable electrodes. Low electrode impedance values also reduce background noise in signal recording for systems like intracortical recording devices.

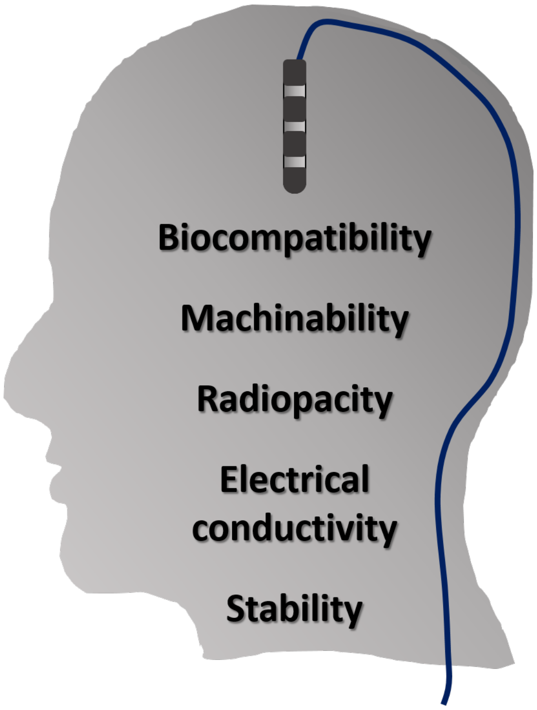

Figure 1: *Schematic of a DBS electrode and important electrode material characteristics*

The electrode material must also be chosen for stability and biocompatibility in its intended biological milieu. In general, precious metals show excellent compatibility and stability in their intended systems, due to their resistance to corrosion and oxidation. Noble metals like gold, platinum, and iridium generally do not require any sort of surface passivation or functionalization prior to implantation into the human body. Gold and platinum alloys are also unlikely to degrade under applied current. Platinum alloys have a history of success in medical implants and electrodes, largely for this reason.[2]

For specific implantable electrodes it is important that the material maintain a certain level of dimensional

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stability and mechanical behavior, requiring strength and predictable load-deflection characteristics. This is often achieved by using platinum-iridium alloys[3], which are stronger and harder than their pure platinum counterparts, but maintain the desirable attributes already discussed.

Precious metal alloys also offer radiopacity, an important characteristic for implantable electrode materials. After implantation, it is common to view implanted electrodes radiographically over time in order to monitor their position and any tissue responses.[4] Platinum and gold alloys both offer high X-ray radiopacity.

Precious metals alloys are used today in a very wide variety of implantable medical electrodes, and some clinically available devices and their applications are listed in Table 1. Platinum and platinum-iridium are the most commonly used precious metal implantable electrode components and can be found in pace makers, nueromodulators, and deep-brain stimulation (DBS) electrodes. Gold wires have been used in neurotrophic electrodes[5] and cochlear implants.

Table 1: *Clinically available implantable electrode systems made using various precious metal alloys.*

Implantble Electrode	Details	Reported Electrode Material	Company
Wire Cortical Strip (WCS®)	Neuro-Stimulation and Recording Device	Platinum	Wise Srl
SENSIGHT™ DIRECTIONAL LEADS	Deep brain sensing/stimulation directional lead	Platinum iridium	Medtronic (Neuromodulation)
FLEX Series Electrode Arrays	Electrode arrays for cochlear implants	Platinum; Platinum-iridium	MED-EL
INGEVITY™ MRI Pacing Lead	MRI Pacing Lead for permanent implantation for atrial or ventricular applications	IROX™ (iridum oxide) coated platinum-iridum	Boston Scientific
Vercise™ DBS System	DBS system for Parkinson's, dystonia, and essential tremor	Platinum/Iridium	Boston Scientific
St. Jude Medical Infinity™ DBS Systems	DBS leads and extensions	Platinum Iridium	Abbott (Neuromodulation) Laboratories
LivaNova® VNS Therapy® System	Vegas nerve stimulation (for epilepsy treatment)	Platinum/Iridium Alloy	LivaNova

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Precious metal coatings like iridium oxide have become popular in the field of implantable electrodes because of the increased electrochemical surface area they offer, which decreases overall electrode impedance. Lower electrode impedance values can improve device battery life.[6] New research has evaluated precious metal coatings on non-metallic substrates for implantable electrode applications. These coatings claim high surface area, beneficial electrocatalytic effects, and increased compatibility with specific biological tissues and systems[7] , but have attendant risks and failure modes common to all coated biomaterials.

DNI is practiced in constructing stable, implantable electrode devices from our precious metal alloys, and can assist with materials selection to design successful implantable electrodes in new devices.

References:

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