Design, Fabrication and Test of a New Technology for MRI-Compatible Deep Brain Stimulation (DBS) Implants

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Since the FDA approval of Deep Brain Stimulation (DBS) in 1997 for the treatment of movement disorders such as Parkinson's disease, there has been a consistent rise in the number of chronically implanted devices. The annual DBS procedures now exceed 12,000[1]. DBS devices involve electrodes connected to an implantable pulse generator through an extension lead, typically containing Platinum microwires routed beneath the skin, which deliver electrical pulses to specific brain regions. Despite the precision and selectivity of modern DBS leads, they still exhibit poor compatibility with magnetic resonance imaging (MRI) as the metal wires can act as antennas, causing excessive heating of the implanted electrodes and posing a risk of tissue damage for the patients.

In response to this limitation, our research is dedicated to developing an innovative metamaterial-based technology for manufacturing internal microwires of DBS implants, ensuring safe operation with 3T MRI scanners. The proposed technology involves layering two metal segments with distinct impedance and conductivity on a substrate microwire, creating an abrupt variation in electrical properties at the interface. This disruption effectively mitigates radiofrequency (RF)-induced currents, reducing electrode heating, specific absorption rate and MRI artifacts.

A cylindrical, non-conductive, and non-magnetic microwire made of a composite biocompatible material was used as substrate. Gold and titanium were deposited onto the substrate in different thicknesses to create the two segments of the design through physical vapor deposition (PVD). Photolithography techniques facilitated the PVD process by securing the wire in place and aiding in the creation of the two segments. Finally, parylene-C conformal coating provided the necessary insulation and protection for tissue implantation. The fabricated wires underwent testing in 1.5T and 3T MRI scanners using a gel-like phantom to mimic human tissue, with temperature probes monitoring variations at the tip during scans.

The fabricated microwires exhibited a resistance of approximately 500Ω and during experimental testing demonstrated a temperature increase of less than 1.5°C at both 1.5T and 3T. In contrast, a control all-gold wire heated up to 10°C under the same conditions. This innovative metamaterial-based technology holds promise in effectively addressing the compatibility issues of DBS leads with MRI, thereby enhancing patient safety during imaging procedures.

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[1] Brooks A, Hoyt AT. Single-Stage Deep Brain Stimulator Placement for Movement Disorders: A Case Series. Brain Sci. 2021 May 3;11(5):592. doi: 10.3390/brainsci11050592.

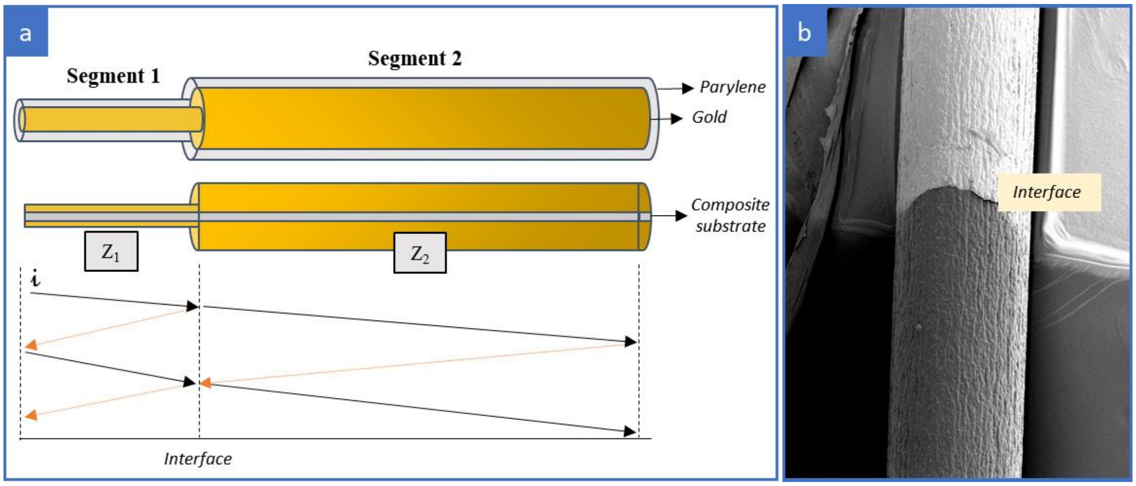

Figure 1. Schematic view of the technology designed for MRI-compatible DBS microwires. (a) The two gold segments of the microwire with different electrical properties (i.e., impedance and conductivity). At their interface, an abrupt change in impedance (Z) causes the reflection of RF-induced current (i) during MRI scans. (b) Image of the interface between the two segments, captured with a scanning electron microscope (SEM).