DREXEL UNIVERSITY
College of
Engineering
Materials Science and Engineering

Department of Materials science and Engineering
PhD Dissertation Proposal

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Online Teams link

Fundamental insights into electrochemical and antibacterial behavior of metal oxide coated hierarchically restructured implantable electrodes for neural stimulation devices

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Abstract

Implantable electrodes serve as the critical interface between neural stimulation devices and neural tissue. Hierarchical surface restructuring (HSR™) of metallic electrodes has emerged as a powerful approach to enhance their electrochemical performance. The introduction of micro and nanoscale features significantly increases charge storage capacity and reduces impedance, establishing HSR electrodes as strong candidates for advanced neural implants. Building on these advantages, adding antibacterial functionality and ensuring long-term electrochemical stability are key next steps for their clinical application. This research investigates the coating of antibacterial metal oxides, such as ZnO, CuO, and Cu_2O, onto HSR electrodes using sputtering deposition. The work aims to provide fundamental insights into how coating parameters like oxide type, film thickness, and degree of conformality govern both antibacterial activity and electrochemical behavior. Initial findings show that ZnO coated Pt10Ir HSR electrodes preserve conductivity while exhibiting enhanced specific capacitance and antibacterial effects through Zn_{2+} release. In parallel, Ti-based HSR electrodes, a more cost-effective alternative, demonstrate electrochemical performance comparable to Pt10Ir HSR electrodes. Looking ahead, the electrode kinetics of ZnO, CuO, and Cu_2O coatings on Ti HSR electrodes will be investigated to elucidate the mechanisms governing electrochemical evolution of hierarchically restructured surfaces modified with different metal oxide layers across varying thicknesses. A comparative study will be carried out to correlate the redox behavior of CuO (Cu^{2+} rich) and Cu_2O (Cu^{+} rich) coated Ti HSR electrodes with the mechanisms responsible for their antibacterial activity such as ion-release concentration and ROS (reactive oxygen species) generation. By systematically unraveling these relationships, my dissertation will advance the core understanding of how antibacterial coatings impact electrochemical behavior, thereby guiding the design of durable, multifunctional HSR electrodes for neural stimulation devices.