Bioactive Nanostructured Materials for Neural Interfaces

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Statement of Purpose: Neural microelectrodes are designed to provide control signals for neural prosthetic devices via transduction of biological signals to electronic signals (1-3). The interface between neural tissue and microelectrodes plays a significant role in the long-term performance of these devices. Unfortunately, only a minority of the recording electrodes on these devices continue to function for long periods of time. Cellular reactive responses that are thought to contribute in device failure include an early acute inflammatory response due to insertion trauma and a chronic foreign body reaction induced by tethering, micromotion and device biocompatibility(4, 5). The objective of this project is to develop biocompatible, bioactive conducting polymer coatings and controlled drug delivery system to improve the electrode-tissue interface and long-term performance of the neural microelectrodes in-vivo.

Methods: We have successfully established a method for fabrication of multi functional coatings for neural microelectrode arrays using electrospinning of anti-inflammatory drug- incorporated biodegradable nanofibers, encapsulation of these nanofibers by alginate hydrogel layer and eventually electrochemical polymerization of conducting polymers on the electrode site, around the drug loaded electrospun nanofibers, and growing within alginate hydrogel matrix.

Results: Diameter of DEX loaded nanofibers varied from 20 nm to 200 nm. The side view optical microscope image revealed that PEDOT was grown vertically from the conductive site, around the electrospun nanofibers and gradually expanded throughout the hydrogel structure with cloud-like morphology. The thickness of hydrogel was 200 ± 6 µm in hydrated condition after 4 dipping cycles in 1% wt alginate and 0.5 M $CaCl_2$ solutions After PEDOT deposition, the impedance decreased significantly at 1 kHz by about 4 orders of magnitude, a net decrease of 2 orders of magnitude from unmodified electrode. The alginate hydrogel coating could decline the burst effect and release profile of dexamethasone about 20%. The initial impedance of the bare gold sites was 800 ± 20 kΩ and then decreased to a minimum of 25 ± 2 kΩ after PEDOT deposition within the hydrogel matrix.

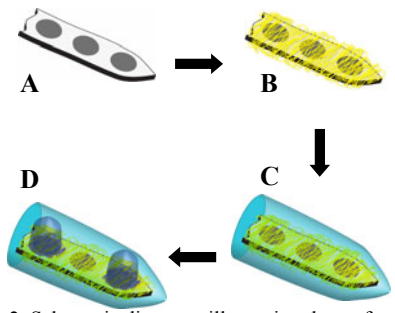

Figure 2. Schematic diagrams illustrating the surface modification of neural microelectrodes.(A) Neural microelectrode, (B) electrospinning of biodegradable polymer (PLGA) fibers, (C) hydrogel coating around the neural microelectrode (D) Electrochemical polymerization of conducting polymers on the electrode sites, around the electrospun nanofibers and through the hydrogel scaffold.

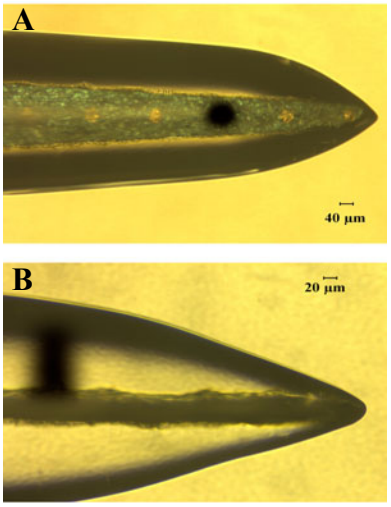

Figure 2. Optical micrographs of conducting polymer grown around electrospun nanofibers and through the alginate hydrogel on the neural microelectrode. (A) Top view, (B) side view.

Conclusions: In this study we developed methods for: 1) sustained release of anti-inflammatory drugs such as dexamethasone (DEX) from the neural electrodes using biodegradable electrospun nanofibers such poly (lactic-co-glycolic acid) (PLGA) and biocompatible alginate-hydrogel. It has been demonstrated that alginate hydrogel coating could not only decrease the burst effect of dexamethasone release for controlling the long-term release patterns but also create a scaffold matrix for growing PEDOT within the alginate in order to increase the conductivity of electrode sites. We believe this method provides a generally useful means for creating low impedance controlled bioactive molecules coating for the neural prostheses and biosensors applications.

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