Polypyrrole-coated nanostructured electrodes to improve impedance and controlled local anti-inflammatory drug delivery.

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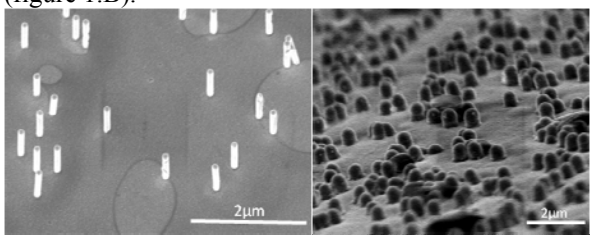
Statement of Purpose: In recent years, nerve implanted prostheses have proven great interest for the recovery of damaged neurological functions by the electrical stimulation of the peripheral or central nervous system. The small size of such prostheses requires optimized geometry and electrical properties for sufficient recording/stimulating ability. This involves a close and long-lasting contact between the stimulation electrode and the biological tissues. Improving this contact is one of the main challenges that must be faced in the development of long-term active implantable stimulators.

One of the biomaterials strategies currently explored is the modification of the electrode surface in order to minimize or eliminate the undesired early inflammatory tissue reaction induced by the surgical implantation. This can be done by the controlled delivery of anti-inflammatory biomolecules in the vicinity of the implant [1]. In this respect, conducting electroactive polymers and among them polypyrrole (PPy) offer an interesting possibility of controllable drug administration through electrical stimulation [2-4]. Moreover, the structural modification of the metallic electrode surface can lead to the improvement of the stimulation properties [1]. In this communication, we report on the development of nanostructured electrodes covered with PPy for the local and electrically controlled of anti-inflammatory biomolecules [5].

Methods: The preparation of nanostructured metallic electrodes is based on a hard templating method. In this study, platinum was electrochemically deposited into the nanoscopic pores of a polycarbonate membrane supported on an Au-coated silicon wafer. The nanostructuration was revealed by the further dissolution of the polycarbonate membrane, leading to the formation of a platinum nanopillar array (Figure 1.A). Then, a one-step electropolymerisation procedure at 0.8V(vs Ag/AgCl) was used to deposit, on the nanopillar array, a PPy film doped with dexamethasone 21-phosphate disodium salt (DEX), chosen as the model biomolecule to be released (figure 1.B).



(A) (B)

Figure 1. SEM pictures of a bare Pt nanopillar array (A) and of a Pt nanopillar array covered with a thin PPy/DEX film (B)

The electrical properties of the electrodes were evaluated with electrochemical impedance spectroscopy (EIS). The DEX was released from the coated nanostructured electrodes using CV stimuli between -0.8 and 0.8V(vs Ag/AgCl) in the presence of PBS buffer. The amount released was quantified using UV spectroscopy at 242nm.

Results: Pt nanowire arrays with an average pillar height of 500nm were synthesized. This height was controlled by the electric charge passing through the sample during synthesis. The influence of this nanostructuration on the electrical properties was studied with EIS. It was shown that the impedance module is decreased in bare Pt nanopillar arrays compared to bare flat gold electrodes. Then, by controlling the polymerization parameters, we could reproducibly prepare nanostructured electrodes covered with PPy/DEX films of different thicknesses. A decrease of the impedance module at low frequencies was observed in the presence of the polymer coating compared with non-coated electrodes. This decrease depends on several parameters such as the film thickness.

As a control, UV readings were taken from coated electrodes to which no electrical stimulus was applied. There was no significant release of DEX by simple diffusion, indicating that the system is truly electrically controlled. Moreover, the amount of liberated molecules was related to the number of CV cycles by a first order kinetics. Finally, the performances of nanostructured PPy/DEX coated nanostructured were compared with planar PPy/DEX coated electrodes. It appears that the adherence between the polymer and the electrode and the electroactivity of the PPy coating are improved in the presence of metallic nanowires.

Conclusions: We have developed a method which allows the easy and reproducible fabrication of PPy-coated nanostructured electrodes for the electrically controlled delivery of anti-inflammatory molecules. The interfacial contact between electrodes and biological tissue can thus be improved at a long-term scale. Besides anti-inflammatory drug, a wide range of biomolecules can be delivered with this system and these nanoelectrodes can be easily integrated into any implantable device using the pre-existing electronic circuits.

References:

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