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Investigation of post-fabrication thermoforming processes on electrode properties using electrochemical impedance spectroscopy on a 3D Parylene sheath probe

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The ability to establish reliable chronic interfaces between tissue and microelectrodes remains a major challenge towards practical clinical neuroprosthetics for the central nervous system. To address this need, we developed a 3D Parylene sheath probe for chronic neuronal recording. Biocompatible Parylene C is an ideal substrate for this application as it has a low Young's modulus that produces an improved mechanical impedance match with brain tissue as compared to more commonly used substrates, such as silicon or metallic microwires, and may improve chronic recording quality. The probe's sheath geometry allows for placement of 4 electrode sites on both the interior and exterior (for a total of 8 recording sites) and produces a conduit for neurite ingrowth, both isolating neuronal signals and integrating the probe with the surrounding tissue. Ingrowth and reduced immune response are facilitated by the use of biofunctional coatings on the sheath surfaces.
The Parylene C sheath was formed post-fabrication through a two-step process that involved gentle mechanical expansion of the initially flattened sheath with a microwire and the thermal annealing of the opened sheath in the presence of the same microwire. The thermal annealing process also promoted the adhesion of the multi-layer Parylene-metal structure. Following thermoforming, the microwire was removed and sheath retained its shape. Throughout these processes, the electrode sites were subjected to mechanical strain (curvature during sheath formation) and thermal annealing. Through the use of electrochemical impedance spectroscopy, we will present a systematic characterization of the electrode surface properties at all stages of the fabrication process: as fabricated, post-sheath opening, post-heat treatment, and completely thermoformed (post-sheath opening and post-heat treatment). We demonstrated that the impedance of the interior electrodes decreased following mechanical microwire expansion of the sheath suggesting the collapsed sheath may obscure the conductive path in the solution. Subsequent thermal annealing also produced a decrease in impedance although lower in magnitude compared to the initial sheath opening step. This decrease may be attributed to the stress relief and associated resistance decrease following annealing of the sheath probe. Preliminary results demonstrate minor changes in impedance following mechanical and thermal processing.

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