A thiol-ene / acrylate thermoset polymer as flexible substrate for implantable electronics

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Using mechanically adaptive neural interfaces has become a promising research strategy to improve on the chronic stability of biotic-abiotic interfaces. In previous work, thiol-ene / acrylate shape memory polymers (SMPs) have been used to fabricate neural interfaces that can be implanted stiff to enable precise insertion and can subsequently soften in physiological conditions to minimize modulus mismatch with tissue [2013.Ware, 2013.Simon]. In this work, high charge-injection capacity electrode materials are incorporated onto SMP-based mechanically adaptive substrates. For the first time, these processes enable integration of iridium and titanium nitride electrodes onto softening substrates using photolithography to define all features in the device. Importantly, no electroplated layers are utilized leading to a highly scalable method for consistent device fabrication. The iridium and titanium nitride electrode are metallically bonded to the gold conductor layer, which is covalently bonded to the softening substrate via sulfur-based click chemistry.

The SMP-based neural interfaces with iridium electrodes can deliver more than 2 billion symmetric biphasic pulses (100µs/phase), with a charge of 200 $\mu C/cm^2$ and geometric surface area (GSA) of 300 μm^2. Electrical stability of iridium is tested under simulated physiological conditions in an accelerated electrical aging setup with periodic measurement of electrochemical impedance spectra (EIS) and charge storage capacity (CSC) at various intervals. Electrochemical characterization, and both optical and scanning electron microscopy suggest significant breakdown of the 600 nm thick parylene-C insulation, although no delamination of the conductors or of the final electrode interface was observed. Minor cracking at the edges of the thin film iridium electrodes was occasionally observed. SMP neural interfaces with TiN electrodes were tuned for improved electrochemical properties; roughness as function thickness and stoichiometry were controlled to maximize the electrochemical surface area (ESA) of the interface.

Besides presenting our results on the successful integration of high charge-injection capacity materials onto thiol-ene / acrylate thermoset polymer substrates, we will also summarize the limitations of SMP substrates for applications in flexible electronics in general.

References

2013.Ware "Thiol-ene / acrylate substrate for softening intracortical electrodes," Journal of Biomedical Materials Research B, volume 102, page 1.

2013.Simon "A comparison of polymer substrates for photolithographic processing of flexible bioelectronics," Biomedical Microdevices, volume 15, page 925.